Time and Timekeepers

Including the History, Construction, Care, and Accuracy of Clocks and Watches

BY

WILLIS I. MILHAM

METEOROLOGY

HOW TO IDENTIFY THE STARS

Frontispiece

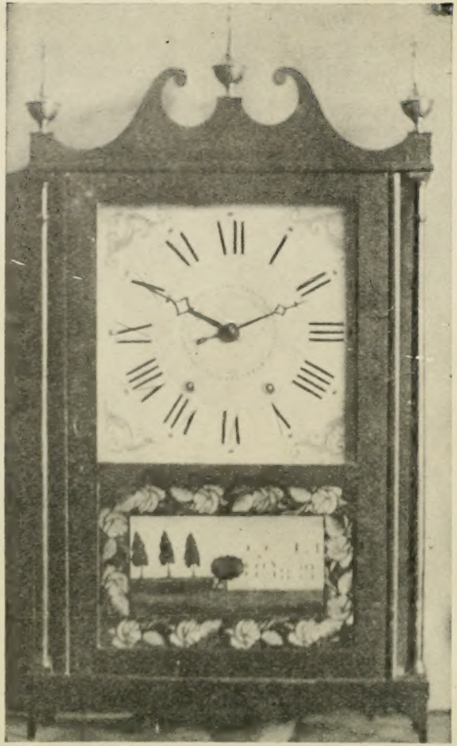

FIG. 242. — A TERRY SHELF CLOCK.

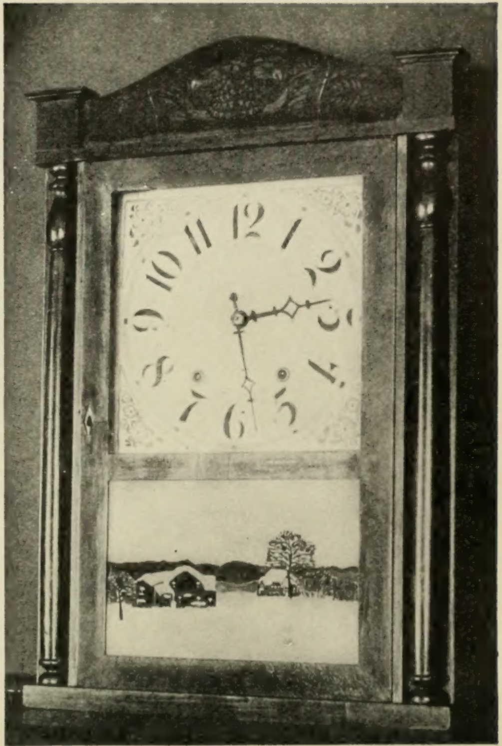

FIG. 243. — A LATER FORM OF THE TERRY CLOCK.

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The History, Construction, Care, and Accuracy of Clocks and Watches

BY

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Preface

This book owes its existence to a course on "Descriptive Astronomy" which the author has given in Williams College for nearly twenty years. One of the topics in this course was "Time and Timekeepers." It was a topic which always aroused much interest in the students and caused a desire for more information. For this reason it was treated at perhaps greater length than is usually the case in a course on Astronomy. The material and illustrations gathered for this topic made the first small beginning for this book.

From that time on no opportunity was neglected to visit museums or to inspect private collections of historic timepieces both in Europe and America. Practically the whole literature of the subject was searched. Watch and clock factories were visited. Many hours were spent with watch and clock repair men in learning the methods of repairing, cleaning, and adjusting timepieces. The booklets, catalogues, and price lists of modern watch and clock manufacturers were carefully read. The behavior of many timekeepers in actual use was obtained. All this material has been welded together and now appears in book form.

The literature on time and timekeepers is large. There are many hundreds of books and pamphlets and many popular and scientific magazine articles. In fact there are several magazines devoted entirely to the subject. Nearly all of the books, however, cover the field with some special aspect of the subject in view. Some treat almost exclusively of the history of watches and clocks. Some consider only the case or housing of the timekeeper and neglect entirely the mechanism. Some treat clocks and watches only from the artistic point of view or as objects for the "Collector of Antiques." Others discuss only the technicalities of construction, while still others are practical manuals for the clock and watch repair man.

This book is intended for the general reader who is interested in time and timekeepers. It is intended for public libraries. It is hoped that the answer to every question which may be asked will be found in this book or that the exact way of gaining the desired information will be pointed out in the extensive classified bibliography. It is intended as collateral reading in courses on Astronomy where time and timekeepers are considered. It is intended for every dealer in antique clocks and watches. It is intended for every purchaser of an antique clock or watch. It is intended for the apprentice and watch repairer, who should know something of the evolution of timekeepers. In short it is intended for every possessor of a timekeeper who is interested in its history, construction, care, and behavior.

The attempt has been made to cover the whole field. For this reason, in order to avoid being superficial, the book has grown to considerable size. It can lay no claim to completeness, however. No single volume can cover all phases of the subject fully. A full, carefully classified bibliography of the subject is placed at the end as an appendix. Here the way is pointed out for the further acquisition of information on the part of him who desires it along any line. This is in a sense a "first book on the subject" as no previous knowledge, particularly of technicalities, is assumed.

This book, then, starts at the beginning, assumes no previous knowledge of the subject, covers the whole field with reasonable fullness, and points the exact way for the gaining of more information.

Each chapter of the book has been made as nearly complete in itself as possible. Thus nearly every chapter can be read independently of the rest of the book. This allows a reader interested in one special thing to read the chapter dealing with it and to omit the rest of the book if he so desires. Certain chapters are closely related, however, and if grouped together would form a treatise on a certain subject. Thus chapters VIII, IX, XIII, XIV, XV, XXI, XXII, and XXIV would form a connected treatise on the watch.

Chapters V, XI, and XII would form a treatise on clock mechanism. Chapters XX, XXI, and XXII would form a treatise on clockmaking and watchmaking at the present time.

In choosing the illustrative material, preference has been given to public museums rather than private collections. The reason is obvious namely that a private collection is not accessible to the public. The preference has also been given to American museums rather than foreign, for the reason that most of the readers of this book will live in America.

In concluding a preface it is not only a duty but a real pleasure to mention those who have been of particular assistance. In this respect I should like especially to express my thanks and appreciation to the Metropolitan Museum of Art in New York City, the Boston Museum of Fine Arts, Essex Institute in Salem, the British Museum, and the South Kensington Museum in London, and the Louvre in Paris, not only in the abstract for permission to examine objects and reproduce photographs but also to those in charge of the sections which have to do with watches and clocks for their personal interest and helpfulness;

To many watch and clock factories throughout the world, particularly to the Howard Watch Co.; the Waltham Watch Co.; and the Seth Thomas Clock Co. in the United States; L. Leroy & Cie, of Paris; Patek, Philippe & Cie and Vacheron and Constantin, of Geneva, and Paul Ditisheim at La Chaux-de-Fonds;

To the observatories at Besançon, Geneva, and Neuchâtel, where timekeepers are tested and much valuable information was obtained;

To Percy Webster and his son Malcolm R. Webster of 37 Great Portland St., London, who are not only in the business of selling antique watches and clocks but are gentlemen who are thoroughly interested in the subject and are glad to go out of their way to give assistance;

To Paul Ditisheim of La Chaux-de-Fonds, who is not only a watchmaker but who is also a gentleman profoundly in-

terested in all research in connection with watches and clocks and glad to be of assistance;

To Henri Bouasse, professor of Physics at the University of Toulouse in France, who has just published two volumes on *Pendule, Spiral, Diapason*, for his kindly interest during a stay of five months in that city;

To the National Museum, the United States Naval Observatory, and the Bureau of Standards in Washington for the valuable material which was obtained and to Mr. A. F. Beal, the head of the watch testing section of the Bureau of Standards, for his painstaking assistance.

W. I. M.

Williamstown, Mass.
June 1923

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Time and Timekeepers

CHAPTER I

TIME[1]

Definitions. — Time is usually defined as *measured duration.* The first of these words suggests units in terms of which to make the measurements and instruments, such as clocks and watches, to do the measuring. The second word suggests a philosophical concept. Our sense of duration, together with our space perception, and our certainty of the existence of material objects around us, are among the most fundamental concepts of the human mind. It is not our purpose here to discuss these abstract philosophical questions but to busy ourselves with the more concrete and definite matter of *measuring* time.

There are four kinds of time: (1) *Sidereal* time, (2) *true* or *apparent* solar time, (3) *mean* or *local* solar time, and (4) *standard* solar time. Of these, sidereal time will be found only in astronomical observatories, but there it plays a very important and fundamental part. The three kinds of solar time form in a way an historic sequence. True solar time was used when sun-dials were the only timekeepers, or rather time indicators. The trouble with true solar time is that the actual duration of the various days is different in different parts of the year, so that no simple watch or clock could keep this kind of time. When mechanical timekeepers came into general use and became at all exact it was discarded in favor of mean solar time. The trouble with mean solar time is that it is different for every place on the earth's surface unless the longitude happens to be the same. It is thus not suited to the close-knit commercial and social

[1] If one is interested primarily in mechanical timekeeping and not in the rather abstract subject of time and the like, the first three chapters may be omitted without breaking the continuity in the least.

life of to-day. It has therefore been discarded in favor of standard time, which is practically universal now and is the only kind of time met with in ordinary life. It will be shown later that sidereal time and apparent solar time are the only two which can be obtained by observing the heavenly bodies with suitable instruments. The other kinds of time must be obtained by computation from them.

To measure time there must be some event which repeats itself again and again with perfect regularity and precision. The rotation of the earth on its axis is taken as such an event and in the ultimate analysis is the measurer for all kinds of time. The earth rotates in $23^h\ 56^m\ 4.09^s$ of ordinary solar time — a little less than a day, a fact not appreciated by every one. The question has been raised as to the regularity of this rotation. Some of the greatest astronomers, including Simon Newcomb, have investigated it. The conclusion is that during the last several centuries the time of rotation has certainly not changed by 0.001^s of time. But even this change would make an accumulated error of nearly $\frac{1}{3}$ of a second in a year or about 37 seconds in a century — a quantity easily measured. There is some evidence that the accumulated error has amounted at times to 3 or 4 seconds but not more. The earth is thus wonderfully regular in its rotation.

Sidereal time depends upon the position with reference to the meridian of the vernal equinox which is a point on the sky fixed among the stars. When the earth by its axial rotation brings the vernal equinox to the meridian of any place, the sidereal time is $0^h\ 0^m\ 0^s$; a new sidereal day begins. When the vernal equinox has completed its circuit and again returned to the meridian, the sidereal time should again be 0; the sidereal day has ended. This time interval is slightly shorter than an ordinary solar day. In these statements two terms have been used which are borrowed from Astronomy. They are *vernal equinox* and *meridian*. These terms may be familiar to all, but nevertheless it will not be amiss to define them accurately. To do so requires a slight digression.

The stars shine during the daytime as well as at night. The only reason why we do not see them is because our eyes are blinded by the sunlight which comes from our atmosphere. With a telescope the brighter ones can be seen by day. At any given moment the sun occupies a definite position among the stars on the face of the sky. The sun is not stationary, however, but moves slowly and steadily eastward among the stars. Its rate of progress is not uniform, but it never stops or goes backward. It completes its circuit and returns to the starting point in one year. All this has nothing to do with the rising and setting of the sun, which is caused simply by the earth's rotation, which affects both sun and stars alike. This path of the sun among the stars, which is a great circle on the face of the sky, is called the ecliptic. It is so called because eclipses can occur only when the moon is crossing this path. The position on the ecliptic which the sun occupies on the 21st of March is called the vernal equinox. This date is chosen because it is then that the sun crosses the celestial equator, "the line," as it is popularly called. The celestial equator is the great circle in which the plane of the earth's equator intersects the sky. The north pole of the sky is the point where the earth's axis produced cuts the sky. This point is located in the constellation of Ursa Minor not far from the pole star, Polaris.

The meridian is the north and south line of the sky which passes through the north pole of the sky and the point directly overhead, the zenith.

In Fig. 1 these relations are shown. The inner sphere represents the earth with its equator and axis produced. The outer sphere is the sky and shows the celestial equator and the north pole of the sky. A part of the ecliptic or path of the sun is shown cutting the equator at the vernal equinox.

There are eighty-eight constellations, and twelve of these form a belt with the ecliptic as the central line. This belt is the zodiac and the constellations are: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus,

Aquarius, Pisces. The vernal equinox has been spoken of as a fixed point among the stars. This must be somewhat qualified. It is fixed as far as the unaided eye can detect in a lifetime. It is, however, moving very, very slowly westward along the ecliptic. This is known as the precession of the equinoxes. In Babylonian times it was in Taurus. Since then it has moved back through Taurus past the reddish-white star Aldebaran, past the little group of six or

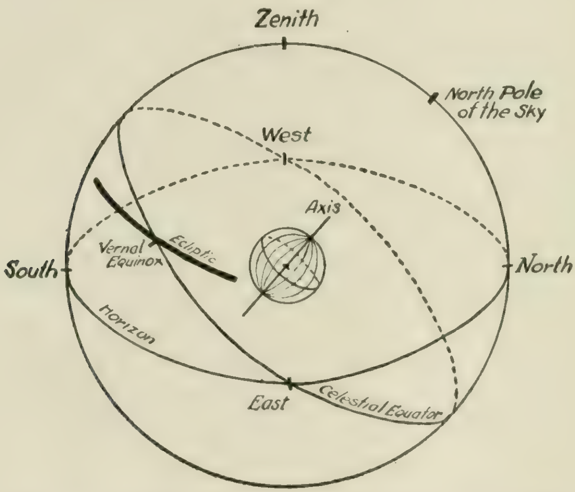


FIG. 1.—DIAGRAM SHOWING THE LOCATION OF VARIOUS POINTS AND CIRCLES ON THE FACE OF THE SKY.

more faint stars called the Pleiades, past three stars which are in Aries and form a little "pulled out" or scalene triangle, back into Pisces, until now it lies close to a very perfect pentagon of faint stars which mark the westernmost part of Pisces. Just above the pentagon is the southern side of the great square of Pegasus. All these stars and constellations lie high up in the southeast and in the east during the early evening in autumn. There is an ever increasing number of people who take pleasure in identifying the stars and constellations. It will be a real pleasure to know this region of the sky. It is shown in Fig. 2.

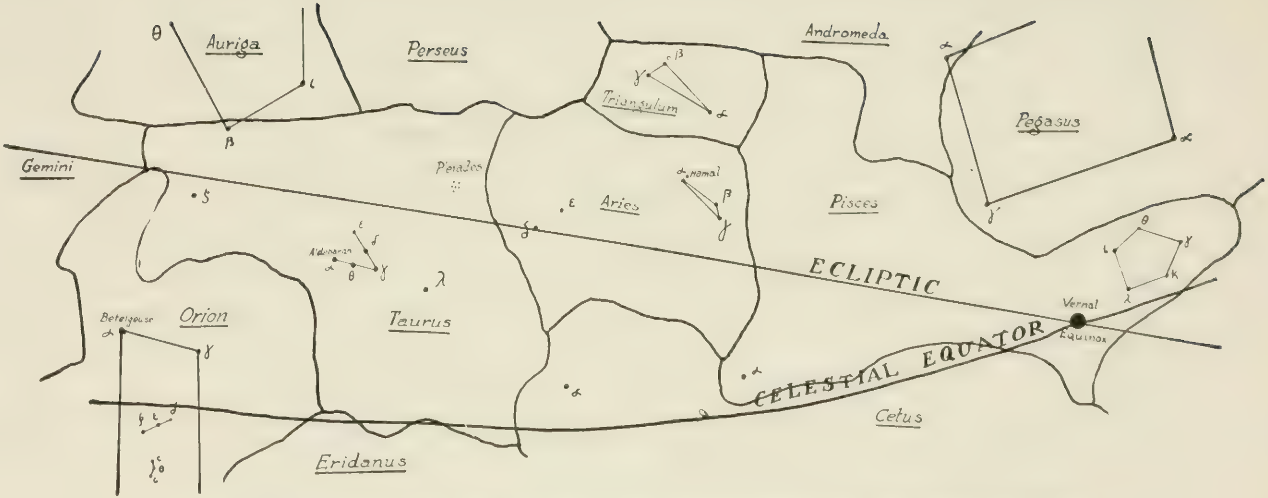


FIG. 2. — THE STARS AND CONSTELLATIONS IN THE NEIGHBORHOOD OF THE VERNAL EQUINOX.

The subject of sidereal time may now be resumed. When the vernal equinox crosses the meridian of a place a sidereal day begins; when it again returns to the meridian, the sidereal day ends. This day is divided like an ordinary solar day into 24 equal hours, numbered continuously from I to XXIV, an hour into 60 minutes, and a minute into 60 seconds. There is no necessary reason for this choice of numbers. There could just as well have been 20 hours in the day or 100 minutes in the hour. It is a Babylonian inheritance, for the Babylonians loved the number 12 and all its multiples and subdivisions. It was their mystic number probably because there are 12 full moons in the course of a year. Thus we have 12 months in the year, 360 (12 × 30) degrees in a circle, 24 (12 × 2) hours in a day, 60 (12 × 5) minutes in an hour, and 60 (12 × 5) seconds in a minute. And what number could be more suitable than 60? It can be exactly divided by all numbers from 1 to 6 inclusive. Thus we can have quarter hours, and five-minute intervals, and ten-minute intervals, and the like. Any watch or clock can be easily made to keep sidereal time by simply causing it to run a little faster than when it is keeping solar time. It will be seen that sidereal time, like all other kinds of time, is really determined by the earth's rotation, which brings the vernal equinox to the meridian or rather the meridian to the vernal equinox, for it is in reality the rotation of the earth on its axis which causes the heavenly bodies to apparently rise, cross the meridian, and set.

Sidereal time may be easily determined with the utmost precision by simply observing the stars. Observing the vernal equinox would be easier, but there happens to be no star at this point. All that is necessary is a star catalogue and a suitable instrument called a meridian circle or transit instrument. The one used at Washington at the U. S. Naval Observatory for determining sidereal time is pictured in Fig. 3. It consists essentially of a telescope at right angles to a rigid axis which should be horizontal and point east and west. The telescope, as it moves, thus

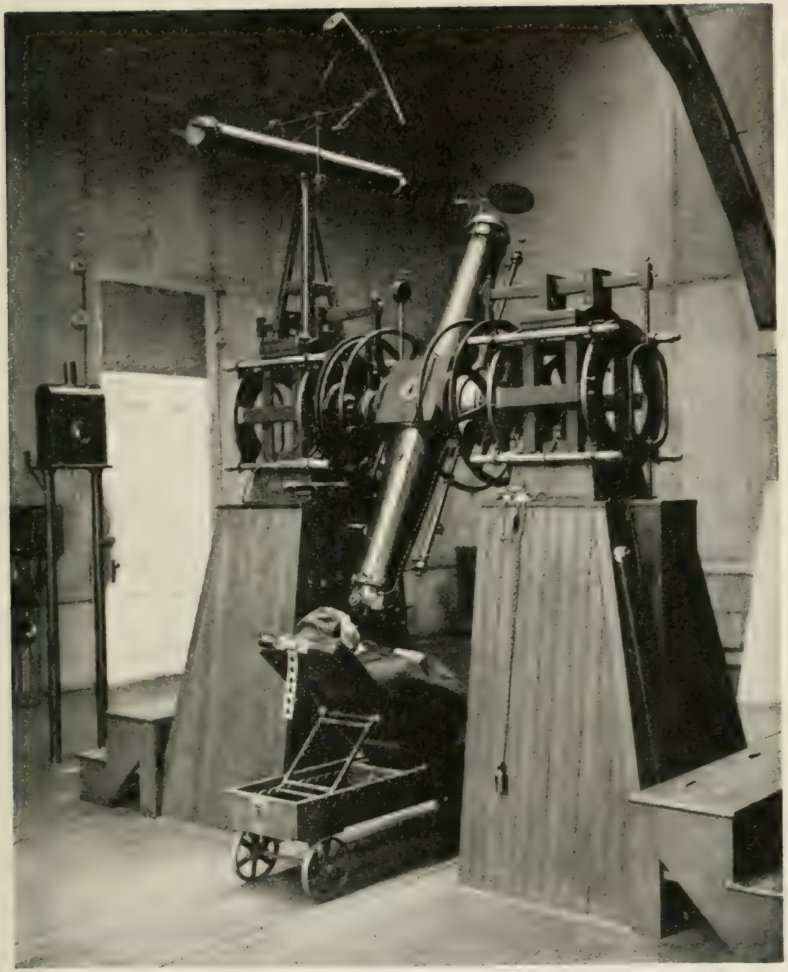


FIG. 3. — THE SIX-INCH MERIDIAN CIRCLE AT THE U. S. NAVAL OBSERVATORY AT WASHINGTON.

traces out the meridian, and stars can be observed only when crossing the meridian. A star catalogue contains a list of stars for which among other things is given their position on the face of the sky reckoned from the vernal equinox and called right ascension. There are many such lists of stars of varying accuracy. A list of several hundred so-called standard stars is contained in *The American Ephemeris and Nautical Almanac.* This is published annually by the U. S. Naval Observatory. A similar year book is also published by Great Britain, France, and Germany. By observing a certain number of these standard stars with a first-class instrument with the greatest of care it is possible to determine sidereal time within a few thousandths of a second. This is the limit of present-day astronomical precision. There are other instruments which can be used and sometimes must be used and there are quite a few other methods of determining sidereal time, but the accuracy is not comparable with that obtained with the meridian circle. Historically, too, other methods have been used earlier, for the transit instrument was first invented by Roemer in the seventeenth century. Thus the truth of the statement that all accurate time comes from the stars!

True or apparent solar time. — Just as sidereal time depends upon the vernal equinox, so true or apparent solar time depends upon the sun. When the center of the actual sun is on the meridian it is true solar noon. When the center of the sun is again on the meridian, it is noon once more and a true solar day has passed. The true solar day is now divided into twenty-four equal hours, usually numbered in two groups from I to XII.

The Babylonian-Greek system was to divide the day, that is the period from sunrise to sunset, into 12 hours and the night into 12 hours. Thus during the summer the daytime hours were longer than the night hours. During the winter the opposite was true. These are often called *temporary* hours. Our own method comes from the Egyptians and Romans, who divided the whole day into 24 equal parts, numbered however in two groups of 12. Thus among

the early peoples and even during the Middle Ages there were various ways in different localities of subdividing the day, and the hour (I) did not always come next to noon and midnight. The Babylonians began their day at sunrise, the Jews and Greeks at sunset, and the Egyptians and Romans at midnight. The reason for having two groups of twelve hours rather than two groups of seven or ten is because it is a Babylonian inheritance.

The great difficulty with true solar time is that the actual duration of the true solar day in various parts of the year is not the same. And the difference in duration is by no means extremely small. For example, if a clock were to run through exactly 24 hours on September 16, that same clock running in exactly the same way would run through 24 hours and 51 seconds on December 23. That solar day has that much longer duration and yet it must be considered to have in it just 24 hours. Each hour must therefore have a little longer duration. No mechanical timekeeper, unless extremely elaborate, could keep this kind of time, and thus true or apparent solar time was discarded in favor of mean solar time. True solar time can be kept only by a sun-dial, but here it is not really kept but only indicated, for it is the sun itself which records its own time.

True solar time may be obtained by observing the sun with suitable instruments. No great accuracy can, however, be obtained, for the sun is too large an object to be observed well and it heats the instruments too much. If an accuracy of 0.1^s were obtained it would be very good.

Mean solar time. — The actual durations of the various true solar days in a year are thus averaged, and the average is called a mean solar day. One can think of mean solar time as depending upon an imaginary, fictitious sun, sometimes called the mean sun, which in the long run keeps pace with the real sun, but which comes to the meridian each day after the lapse of the same interval of time. Sometimes it will be ahead of the real sun and sometimes behind. It will have to move eastward in the equator with

uniform speed because it is the eastward motion of the real sun in the ecliptic with variable speed which causes the true solar days to have different durations. It is mean solar noon when the center of this fictitious sun comes to the meridian. A mean solar day has passed when it again comes to the meridian. A mean solar day is also divided into 24 equal hours, each hour into 60 minutes, each minute into 60 seconds.

Mean solar time cannot be found by observation for the simple reason that there is no object to observe. Mean time is sometimes called local time because each place has its own time. The farther west a place is, the later will the mean sun come to its meridian. It is also true in the case of sidereal time and true solar time that each place has its own time.

The interrelation between mean solar time and sidereal time. — Sidereal time and solar time agree about March 21 because sidereal time is run by the vernal equinox and solar time by the sun, and the sun is in the vernal equinox about that date. From then on sidereal time gains over solar time because the sun moves eastward among the stars and thus comes later each day to the meridian than does the vernal equinox. Thus a sidereal day has a shorter duration than a solar day; a sidereal hour than a solar hour; a sidereal minute than a solar minute. The sun makes a complete circuit of the sky and returns to the vernal equinox in a year. There are thus 365.2422 solar days in a year and 366.2422 sidereal days. An interval of solar time can thus be changed to an interval of sidereal time, or vice versa, by using these numbers as a ratio. A numerical example will perhaps make this clearer. How much sidereal time is there in an interval of 8 solar hours? The answer is 8 times 366.2422 divided by 365.2422, which gives $8^h\ 1^m\ 18.85^s$. Thus 8 solar hours and $8^h\ 1^m\ 18.85^s$ of sidereal time have the same duration. Tables given in *The American Ephemeris and Nautical Almanac* permit this computation to be made quickly without multiplying or dividing by these long numbers.

Sidereal time gains, as we have seen, one day over solar time in a year. This amounts to about two hours a month or a little less than four minutes a day. It is thus possible to compute mentally about what sidereal time corresponds to any solar time. For example, what is the sidereal time at 8 P.M. solar time on November 1? On March 21 the two agree. By September 21 sidereal time has gained 12 hours; by October 21, 2 hours more. In the 11 days to November 1 it has gained about 44 minutes. Thus the total gain is about $14^h\ 44^m$, and the sidereal time at 8 P.M., November 1, should be about $22^h\ 44^m$. This, of course, is a rough computation but is correct within a few minutes.

To determine exactly the sidereal time corresponding to a given mean solar time or vice versa, tables given in *The American Ephemeris* must be used. In one table is given for each day in the year the sidereal time of mean solar noon at Greenwich, and this is the key to the situation. If the longitude of any place is known, then the sidereal time of mean solar noon at that place can be found and from this the sidereal time corresponding to any mean solar time. But these details are interesting chiefly to those who like Mathematics or Astronomy, and a further treatment is thus relegated to Appendix IV. It is sufficient for the general reader to know that by using tables in *The American Ephemeris* the sidereal time can be computed from mean solar time or vice versa with the utmost precision. It takes but two or three minutes to make the computation.

The interrelation between true solar time and mean solar time. — The difference between true or apparent solar time and mean solar time is called the *equation of time*. It is zero several times a year and never has a value as large as eighteen minutes. It may be thought of as the difference between the real sun and the imaginary mean sun which runs mean solar time. These two objects in a sense "play tag" with each other on the face of the sky. Sometimes one is ahead, sometimes the other. They are sometimes together (i.e., cross the meridian at the same time) and they are never as far apart as eighteen minutes.

There are two items or factors which enter into the equation of time. The real sun moves with irregular speed and its path is the ecliptic, whereas the imaginary mean sun moves eastward with uniform speed and in the celestial equator. These two factors must first be considered separately. The irregular speed of the real sun eastward among the stars is due, of course, to the irregular speed of the earth in its orbit about the sun, for it is the real motion of the earth which causes the apparent motion of the sun. The earth is nearest the sun and moves fastest on January 1, which causes the sun to apparently move eastward among the stars with its greatest speed at that time. On July 1 the earth is farthest from the sun and moves slowest. Due to this factor alone, the equation of time would be zero on January 1 and July 1, and have its largest value of a little less than eight minutes in between. The second factor is because the sun's path is the ecliptic, not the celestial equator. It might seem that that ought not to make any difference, but the ecliptic runs "crosswise on the sky," so that even if the sun covered the same space each day, the projections of these equal spaces on the celestial equator would not be equal.[1] Due to this factor alone the equation of time would be zero four times a year at the two equinoxes and the two solstices, that is on about the 21st of March, June, September, and December, and would have its greatest value of about ten minutes in between. To get the actual equation of time the two factors must be combined. This has been done graphically in Fig. 4. The interval in the date is one month and the interval in time is five minutes. The value of the first factor is shown as a dotted curve, while the value of the second factor is given in dashes. The actual equation of time as found by combining the two factors is shown as a heavy line. The value of the equation of time, as will be seen, is zero four times a year at irregular,

[1] If a celestial globe is available it is easy enough to prove this fact. Lay off on the equator and also on the ecliptic 15° spaces, starting with the vernal equinox. These circles will be found drawn on the globe itself among the stars. Now turn the globe slowly and it will be seen that only four pairs of these points come to the brass meridian ring at the same time.

unexpected dates, namely, about April 16, June 15, September 2, and December 25. These are the dates when the heavy line crosses the OX (date) axis in the figure. Its greatest positive value is a little less than 17 minutes on November 3, its greatest negative value is a little less than 15 minutes on the 12th of February. These dates and the diagram are really for the year 1922, which is a middle year between leap years. The fact that there is an extra day every four years in our calendar makes the values

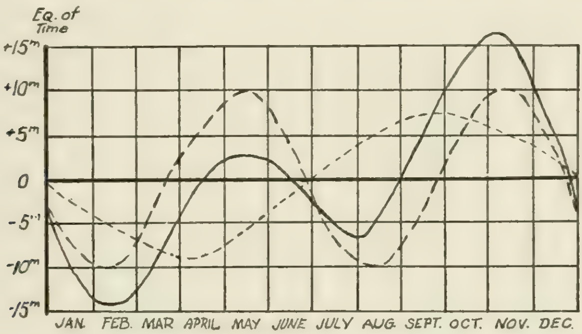


FIG. 4.—THE EQUATION OF TIME AND THE TWO FACTORS OF WHICH IT IS COMPOSED.

(Apparent − Mean = Equation of Time.)

of the equation of time and the dates slightly different in different years.

In the accompanying table the actual values of the equation of time for March 1 (Greenwich mean noon) are given for several years. It will be seen that they differ by about ten seconds, and it will also be noticed that every four years the value goes back to practically what it was four years before.

March 1

1904	$-12^m\ 33.65^s$	1911	40.85^s	1918	35.91^s
1905	35.35^s	1912	33.49^s	1919	38.76^s
1906	38.65^s	1913	35.48^s	1920	31.38^s
1907	41.42^s	1914	38.39^s	1921	33.13^s
1908	32.46^s	1915	40.60^s	1922	36.28^s
1909	36.25^s	1916	30.86^s	1923	39.66^s
1910	37.60^s	1917	34.34^s		

In the accompanying table the values of the equation of time (at Greenwich mean noon) for the 1st, 11th, 21st, and 31st of each month of 1922 are given. They of course correspond with the curve shown in Fig. 4.

Values of the Equation of Time

	1st	11th	21st	31st
January	$-3^m28.04^s$	$-7^m52.59^s$	$-11^m19.12^s$	$-13^m32.19^s$
February	$-13^m41.03^s$	$-14^m23.87^s$	$-13^m49.88^s$	
March	$-12^m36.28^s$	$-10^m18.21^s$	$-7^m27.11^s$	$-4^m25.05^s$
April	$-4^m\ 6.95^s$	$-1^m13.55^s$	$+1^m12.29^s$	
May	$+2^m54.35^s$	$+3^m44.67^s$	$+3^m38.18^s$	$+2^m37.27^s$
June	$+2^m28.66^s$	$+0^m43.96^s$	$-1^m22.74^s$	
July	$-3^m29.25^s$	$-5^m10.51^s$	$-6^m\ 9.52^s$	$-6^m14.09^s$
August	$-6^m11.18^s$	$-5^m\ 8.51^s$	$-3^m10.37^s$	$-0^m26.06^s$
September	$-0^m\ 7.51^s$	$+3^m12.29^s$	$+6^m43.38^s$	
October	$+10^m\ 7.16^s$	$+13^m\ 4.15^s$	$+15^m12.55^s$	$+16^m16.37^s$
November	$+16^m18.73^s$	$+15^m57.40^s$	$+14^m10\ 64^s$	
December	$+11^m\ 4.72^s$	$+6^m54.95^s$	$+2^m\ 4.60^s$	$-2^m51.88^s$

In both diagram and tables the equation of time has been given in the sense, apparent solar time minus mean solar time. The values in *The American Ephemeris* and in many other books are given this way. In some books, however, the equation of time is considered as mean time minus true time. Thus care must always be exercised in connection with the algebraic sign of the equation of time. Consequently if the equation is taken as apparent minus mean, then + means that the equation must be added to mean to get true and − means the opposite. If rough values of the equation of time are desired, they may be taken with sufficient accuracy from the diagram or the table. If exact values are desired, they must be obtained from *The American Ephemeris* for the given year and date. Further details may be found in Appendix IV.

Another method of indicating graphically the values of the equation of time is shown in Fig. 5. Here the values of the equation of time are plotted horizontally and the

dates, starting with December 21, are plotted vertically. The reason for starting with this date is because then the sun stands lowest in the sky at noon. It is possible from this diagram, as well as from the one shown in Fig. 4, to read off the value of the equation of time corresponding to a given date. The declination of the sun (which may be obtained from *The American Ephemeris*) is sometimes used instead of the date for the vertical scale, and sometimes the length of the shadow of an object cast by the son on a horizontal surface in a given latitude. These special ways are of chief use when the curve is to be used in connection with a sun-dial.

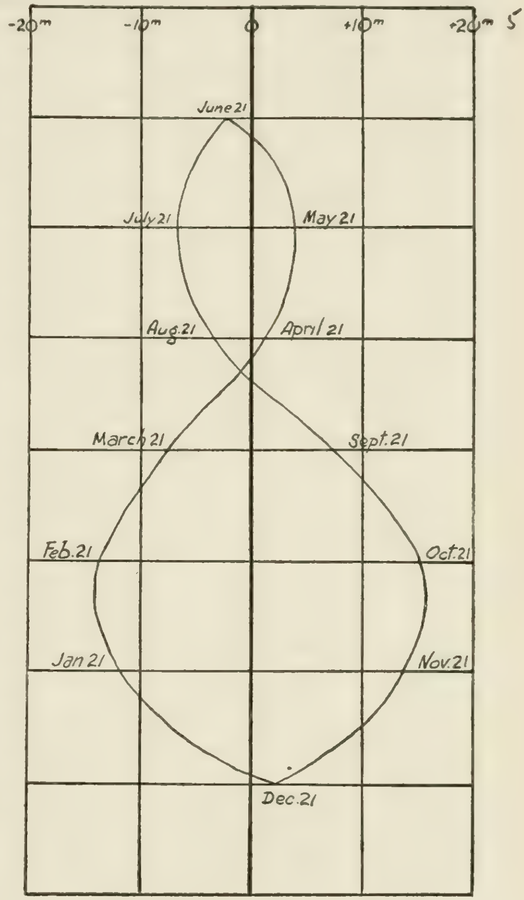


FIG. 5. — A SECOND METHOD OF INDICATING GRAPHICALLY THE VALUE OF THE EQUATION OF TIME.

Standard time.— Just as true solar time gave place to mean solar time when accurate clocks and watches became common, so mean solar time became impossible as means of quick communication and travel increased. Every city, town, and village had its own mean solar or local time, that

is, if they did not happen to have the same longitude. Two places within easy reach of each other might have times differing by seconds, yes, even minutes. Going 12 or 13 miles east or west in lat. 40° to 50° causes a difference of one minute in local time. To obviate this difficulty all places in a given belt would agree to deliberately run their timepieces slow or fast by such an amount that the time everywhere in the belt would be the same.

Historically considered, the desire for this standard or uniform time began to be felt in the United States about 1870 or a little later. The United States invited an international congress, to be held at Washington in 1884, for the purpose of proposing a standard meridian to which longitude and time should be referred. But before this congress met, the present system of standard time had been practically put into operation by the managers of the larger railroads.

There are now five standard time belts in North America. They are called the Colonial, Eastern, Central, Mountain, and Pacific standard time belts. Colonial standard time exists only in Newfoundland and near-by portions of Canada but not in the United States. Eastern standard time differs from Greenwich mean solar time by just five hours, Central by six, Mountain by seven, and Pacific by eight. They are of course all slow as compared with Greenwich time. The boundaries of these belts are not straight and regular because the places near the boundaries usually show strong preferences for being in one belt or the other and have been allowed to choose. Thus the boundaries of the belts are irregular and their actual course across the country (in 1922) is shown in Fig. 6. This map was prepared by the Bureau of Standards at Washington, D. C., and corrected to Nov. 7, 1921.

Standard time is now practically universal throughout the world. It was adopted by nearly all countries between 1890 and 1895. Usually the time differs by a whole number of hours or half hours from Greenwich mean solar time. There are a few exceptions, however. In Belgium, France,

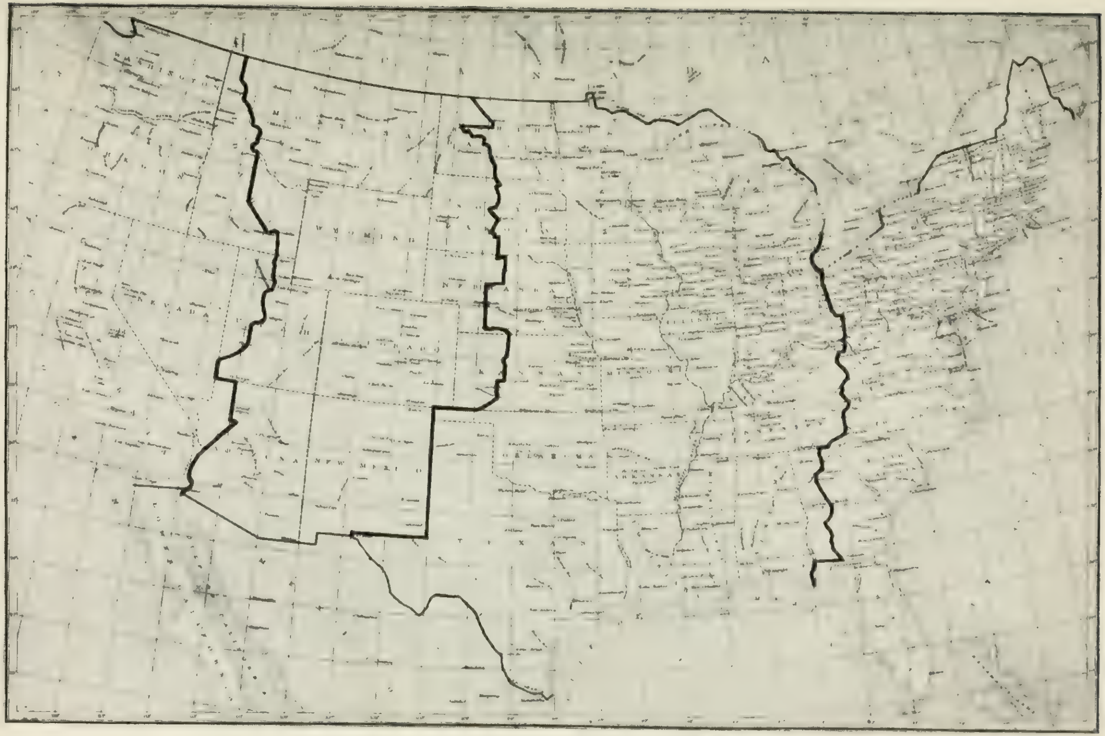


FIG. 6. — THE FOUR STANDARD TIME BELTS IN THE UNITED STATES

(Furnished by the Bureau of Standards, Washington, D. C.)

and Holland Greenwich time is used. Germany, Italy, Switzerland, and Sweden are one hour fast. Japan is nine hours fast. A complete list of the standard times in all countries is given in the publications of the U. S. Naval Observatory, Vol. IV, Appendix IV, Washington, 1906 There have been, however, quite a few changes since 1906.

The relation between the mean solar or local time of a place and the standard time depends simply upon the longitude of the place. Suppose a place is in the Eastern standard time belt and its longitude is $4^h\ 52^m\ 50^s$. Its timekeepers must be kept 5 hours slower than Greenwich time to keep Eastern standard time. For its longitude the timekeepers ought to run only $4^h\ 52^m\ 50^s$ slower. Thus the timekeepers must be deliberately run $7^m\ 10^s$ slower than they should be if they were keeping the mean solar time of the place. Thus a rule for computing mean solar time from standard or vice versa may be formulated as follows: Subtract the longitude of the place from the time hour of the belt. Add this difference (algebraically taking regard of the sign) to the standard time to get mean solar or subtract the difference from mean solar time to get standard. Algebraically expressed:

mean s. t. = standard s. t. + (time hour of belt − longitude)

Summary. — A brief summary of much of the information in connection with the four kinds of time and their

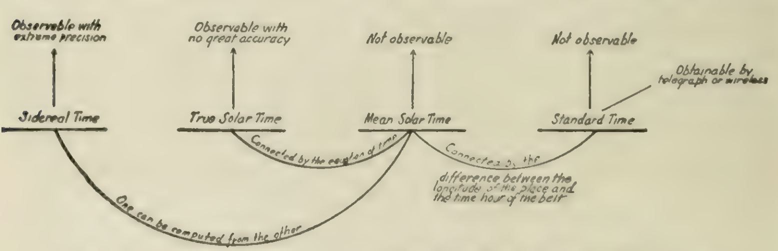


FIG. 7. — THE INTERRELATIONS OF THE FOUR KINDS OF TIME.

interrelations can be given as a diagram (see Fig. 7). Mean solar time and standard time at any given place never differ

Courtesy U. S. Naval Observatory.

FIG. 8. — AN AEROPLANE VIEW OF THE U. S. NAVAL OBSERVATORY AT WASHINGTON.

by more than 30 minutes if a place remains in the belt in which it normally belongs. Mean solar time and true solar time never differ by as much as 18 minutes. Sidereal time and solar are radically different and may differ by any number of hours. Further details in connection with the change from one kind of time to another are given in Appendix IV.

The story of our time service may now be related. It is at the Naval Observatory in Washington, D. C., that time is determined with extreme accuracy and distributed over the whole country east of the Rocky Mountains. An aeroplane view of this observatory is shown in Fig. 8. It is located in Georgetown just outside of Washington. The clock vault is located in the basement of one of the buildings not far from the six-inch transit instrument. The plan of it is shown in Fig. 9. The outer wall is of brick nine inches thick, with a floor consisting of eight inches of concrete and a ceiling composed of six inches of mineral wool. The inner partition is of wood and there is an air space of about a foot between. This space is heated by means of four hot water pipes running almost completely around it and the heating is controlled by a thermostat. The inner vault is about eight feet square and seven feet high. It is heated by means of four incandescent lamps and is controlled by a sensitive thermostat.

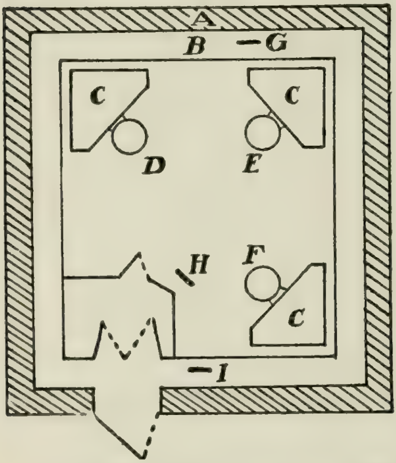


FIG. 9.—THE CLOCK VAULT AT THE U. S. NAVAL OBSERVATORY.

A. A nine-inch brick wall.
B. Wooden partition.
C. The three brick piers.
D. Riefler clock No. 70.
E. Riefler clock No. 60.
F. Riefler clock No. 151.
G. Outer thermostat
H. Inner thermostat.
I. Alarm thermostat.

To reach this inner vault it is necessary to pass through three doors. It contains three brick piers to which are attached the three clocks keeping sidereal time. These are all Riefler precision clocks (see Chapter XIX) and their numbers are 60, 70, and 151. These clocks are in air-tight glass cases and the air has been chemically dried. They are thus housed in the ideal way and are free from moisture, jars, pressure changes, and temperature changes.[1]

Two or three times a week a number of the standard stars are observed using the meridian circle pictured in Fig. 3 and thus sidereal time is obtained with an accuracy of a few thousandths of a second. It is thus known just how much each clock is fast or slow and a continuous record of these clocks is of course kept.

The "distributing clock" or signal-sending mechanism is located in another part of the observatory and is pictured in Fig. 10. In fact there are two, so that if anything should happen to one the other could be used. At about half-past eleven each day its error is determined. This involves the records of the clocks in the vault because to know the exact time at the moment in question it is necessary to know how much each was in error at the last date of observation and how much each gains or loses per day. It also involves the computation of standard time from sidereal, since the clocks in the vault keep sidereal time and the distributing clock keeps Eastern standard solar time. This can be done in a few minutes and the details are given in Appendix IV. Each clock in the vault and the distributing clock have "contact makers," so that it is easy to compare them by means of a chronograph. The distributing clock is adjusted until it is within a few hundredths of a second of correct.

Each day at 11.50 A.M. Eastern standard time the Western Union Telegraph Company suspends its regular work and puts its wires at the disposal of the government for the sending of the time signals. The wires are joined

[1] See "The Clock Vault of the U. S. Naval Observatory," by EDGAR D. TILLYER, in *Popular Astronomy*, Vol. XVIII, No. 2, Feb., 1910.

FIG. 10. — THE DISTRIBUTING CLOCK AT WASHINGTON.

up in continuous closed circuit through the various relays with this distributing clock in Washington. Every second this distributing clock makes contact so that the clicks heard in every telegraph office throughout the country are practically the ticks of a clock keeping accurate Eastern standard time. Certain clicks must be omitted to mark

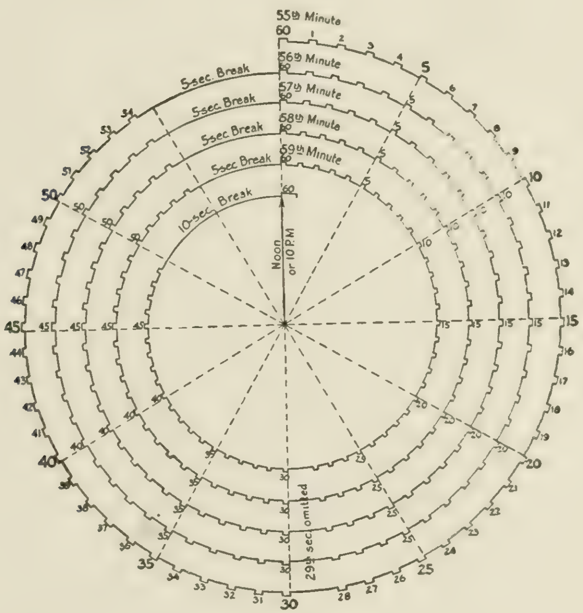


FIG. 11. — ILLUSTRATING THE TIME SIGNALS AS SENT OUT BY TELEGRAPH.

(From Circular No. 51 of the Bureau of Standards, Washington, D. C.)

the minutes and half minutes. Thus the 29th second and the 55th to the 59th inclusive are always omitted. Just before twelve o'clock 10 clicks are omitted, that is, the 50th to the 59th inclusive and the last click at exactly noon is longer than the rest. This is shown graphically in Fig. 11. On the Pacific coast time is sent out at noon Pacific standard time from the Mare Island Navy Yard. Time is also sent out at 10 P.M. both from Washington and

the Mare Island Navy Yard, but the distribution is by no means so general as at noon.

These time signals are remarkably accurate. They are probably never in error by more than a few tenths of a second. Time is determined in Washington within a few thousandths of a second. The distributing clock is correct within a few hundredths. The relays in the telegraph lines introduce most of the error, but in practically every case the signals can be implicitly relied upon to be accurate within a few tenths of a second. If you are interested in your watch and in accurate time, by all means take it to a telegraph office, hear the noon time signal, thus determine for yourself how much your watch is off, and then keep a written record of its behavior. The chronometers in jewelry stores marked "correct time," the so-called "regulators" in jewelry stores, electrically synchronized clocks maintained by the Western Union Telegraph Company may all be correct within a few seconds, but nevertheless the only source of exact time upon which one can implicitly rely is the telegraphic (or wireless) time signals from Washington.

In about twenty harbors of the United States, time balls are dropped at noon. A time ball is a hollow metal sphere about six feet in diameter and having usually a free fall of some twenty feet. It is always located on the top of some high building so that it can be seen far and wide. It is drawn up to the top of the staff a little before twelve o'clock and then allowed to fall so as to be in the middle of its drop at exactly noon. Their purpose is primarily to furnish exact time to the vessels in the harbor and thus obviate the necessity of bringing the timepiece ashore. In Boston the time ball is located on the Ames Building and has been in use for a considerable number of years. In New York a time ball was maintained for more than forty years on the Western Union Telegraph Building, 195 Broadway. This building was gradually surrounded by taller structures and during its last years the time ball was practically invisible. It was discontinued in 1913 when the Western Union moved into its new building. In 1913 a time ball was

installed on the building of the Seaman's Church Institute at 25 South Street on the East River and this service is still maintained.

The Western Union Telegraph Company maintains an elaborate system of electrically synchronized clocks which are giving good service. They are now to be seen almost everywhere and the number is constantly increasing. The cost is from \$15 to \$30 a year, depending on the type of clock and this includes installation, complete maintenance, and the time service. The master clock for a village or a whole city is located in the telegraph office. It is generally a good timepiece, and if properly cared for should not gain or lose more than one or two seconds a day at most. It is set exactly right at noon from the Washington time signals. This master clock synchronizes all the other clocks every hour. These clocks usually carry the label "Naval Observatory Time hourly by Western Union." It may be only a quibble but yet this statement is not quite correct. The clocks are set right hourly by the master clock, but the master clock is set right only at noon by the Washington time signals from the Naval Observatory. When everything is working well no one of these clocks should ever indicate a time inaccurate by more than a second or two. It needs careful attention, however, to keep such a system in good working condition. In Fig. 12 are pictured the master clock and the time service transmitting equipment for New York City.

There are other ways of distributing time throughout a city than by means of electrically synchronized or controlled clocks. In fact electrical clocks are so troublesome that compressed air is often preferred. This is true of the city of Paris. Here there are several thousand clocks which are synchronized (or rather actuated) every minute by compressed air. The reservoir contains air under a pressure of about two atmospheres. This is placed in communication with the pipes for about 20 seconds every minute. Thus the pressure in the pipes rises to two atmospheres and falls again each minute. This change of pressure actuates the controlled clocks. The main pipes have a diameter of

about 27 mm. and the secondary ones a diameter of about 6 to 20 mm. It will be remembered that there are about 25 mm. in an inch.

Any one who has visited the city of Edinburgh in Scotland will surely remember the cannon at the Castle which is fired daily at noon and thus gives the correct time to the city.

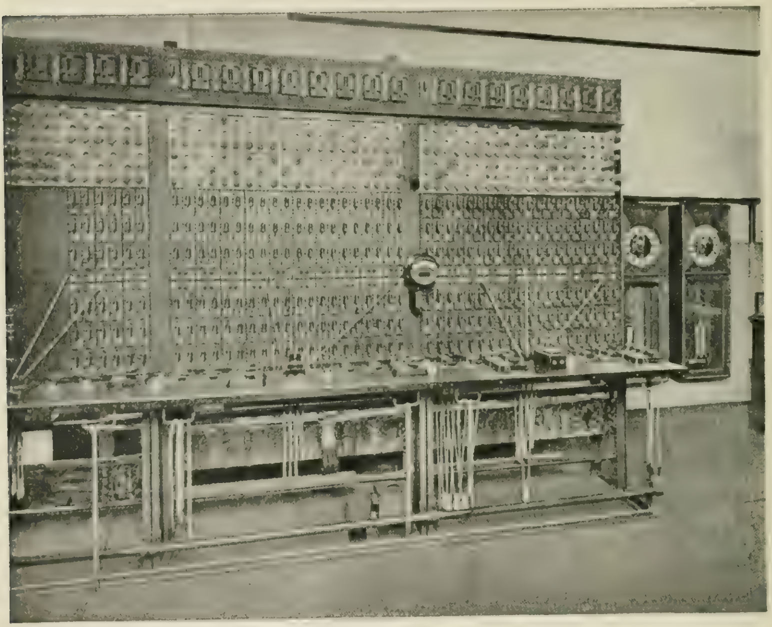


FIG. 12. — THE MASTER CLOCK AND THE TIME SERVICE TRANSMITTING EQUIPMENT FOR NEW YORK CITY.
(Western Union Telegraph Co.)

It must be remembered, however, in connection with any sound signal that sound travels in air under usual conditions only a little more than a thousand feet a second. It thus requires about five seconds to travel a mile.

The distribution of time by wireless.[1] — Time is also distributed by wireless from fourteen stations in the United

[1] See "From Star to Chronometer via Radio," by C. H. Claudy, in *Scientific American*, Vol. CXXV, No. 11, Sept. 10, 1921.

States and its possessions. These are Arlington, Annapolis, Key West, New Orleans, Balboa, Colon, Cavite (P. I.), North Head (Wash.), Eureka (Cal.), Point Arguello (Cal.), San Diego, San Francisco, Great Lakes (Ill.), and Pearl Harbor (T. H.). These stations are widely scattered and the wave length used is quite different. The best known stations are perhaps Arlington (wave length 2500 meters), Annapolis (16,900 meters), Key West (1000 meters), and Mare Island (2500 meters). Time is sent out by wireless at the same time and in the same manner as it is distributed by land wires. Time is also being sent out by an ever-increasing number of broadcasting stations, so that it will soon be within reach of every one by means of radio. The time of sending it out and the accuracy is nearly the same as when sent by the regular stations with a much longer wave. Time is also sent out by wireless from many other stations in the world, so that it is almost impossible at present for a vessel to be anywhere on the seven seas and be beyond the reach of wireless time. On the North Atlantic time is received both from Arlington and from the Eiffel Tower in Paris, which is a very important sending station. Time is also sent from Bordeaux with an undamped wave of 23,400 meters and from Lyon with a wave length of 15,000 meters.

The station at the Eiffel Tower uses a wave length of 2200 meters. The antennae consist of six wires 500 meters long which stretch from the top of the tower to points on the ground at the proper distance. They are of course very well insulated. There is an underground connection between the Observatory at Paris and the Eiffel Tower sending station. The general arrangement of the apparatus is shown in Fig. 13. The circuit from the Observatory to the tower may be closed by the clock *C* at the Observatory or by the astronomer by means of the key *K*. This works the relay circuit, which closes the main circuit, produces the spark, and thus sends the signal. During the night the time is sent out at $23^h 45^m$, $23^h 47^m$, and $23^h 49^m$ Greenwich mean solar time. At about $23^h 44^m$ the astrono-

mer by means of the key sends out a series of preparatory signals consisting of dashes (— — — —). These end at $23^h\ 44^m\ 55^s$, and at $23^h\ 45^m$ exactly the signal is sent by the clock. The astronomer again sends a series of preparatory signals consisting of dashes and two dots (— . . — . . — . .)

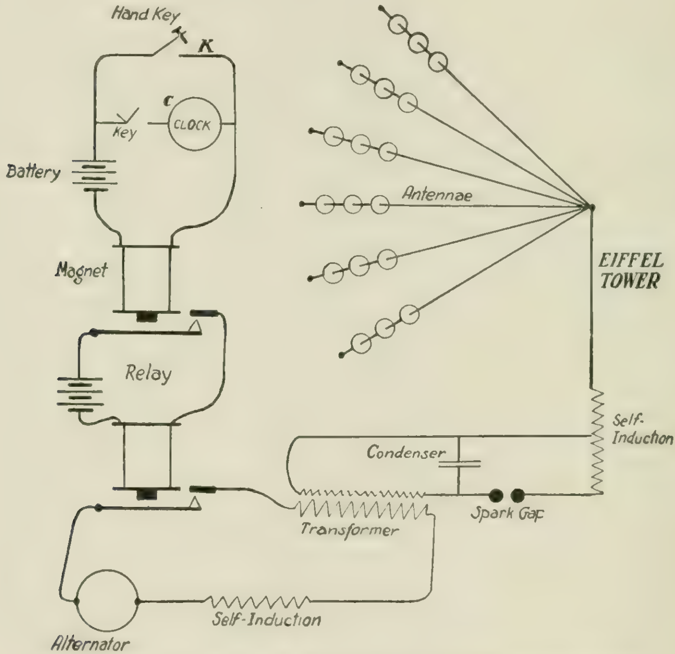


FIG. 13. — THE APPARATUS FOR SENDING THE WIRELESS TIME SIGNALS FROM THE EIFFEL TOWER.

(After BOUASSE, *Pendule, Spiral, Diapason.*)

at $23^h\ 46^m$ and these continue until $23^h\ 46^m\ 55^s$. At $23^h\ 47^m$ the clock sends the second time signal. The astronomer again sends a series of preparatory signals consisting of a dash and four dots (— . . . . — . . . . — . . . .) from $23^h\ 48^m$ to $23^h\ 48^m\ 55^s$. The clock sends the third and last time signal at $23^h\ 49^m$. During the day wireless time signals are sent out by the clock at $10^h\ 45^m$, $10^h\ 47^m$, and $10^h\ 49^m$. There is also the same set of preparatory signals as before.

Time signals of a different nature are also sent by the Eiffel Tower at ten in the morning. These are sent by a special transmitter of high precision which has been synchronized by one of the clocks. These signals, which continue about three minutes, are evident from Fig. 14.

At the Paris Observatory the time is of course determined by star observations. It is kept by means of three excellent clocks. The clock which sends the signals is either No. 1116 or No. 1117 and both were made by Leroy & Cie of Paris. It is set to exact time before the signals are sent by means of a magnetic rectifier.

Signaux envoyés par la Tour Eiffel, de 9 h. 57 à 10 h. 0.

FIG. 14. — WIRELESS TIME SIGNALS SENT OUT BY THE EIFFEL TOWER AT TEN IN THE MORNING.

Time a man-made affair. — It might perhaps be well in closing this chapter to emphasize the fact that standard time, the time of our everyday life, is very much a man-made affair. When the proposal was made to put all timekeepers ahead one hour to effect daylight saving, the cry was heard that it was unnatural, as it did not follow the sun. Man, as a matter of fact, has not followed the sun with his time for many, many centuries. Mean solar or local time may differ from true sun time by as much as 18 minutes and standard time may differ from mean solar by 30 minutes. Thus to set all clocks ahead one hour is only to take one step more. Two steps have already been taken. Another result of our "tampering with true sun time" is evident the first weeks of January

and often causes surprise. When the days begin to lengthen, the effect is all in the afternoon and the mornings even grow shorter. The reason is the equation of time is changing faster than the days are lengthening. This not only throws the whole increase of length into the afternoon but even robs the morning of a few additional minutes.

CHAPTER II

THE SUN-DIAL

The origin of the sun-dial. — The first timekeeper or rather time indicator to be used was without doubt the sun-dial. Herodotus, a Greek historian of the fifth century B.C., states that the sun-dial came from Babylonia. There are other lines of evidence as well, so that it is safe to conclude that the sun-dial was in use in the valleys of the Tigris and the Euphrates at least as early as 2000 B.C. Of course we do not know the form and appearance of these early instruments and neither do we know the gradual development by which the primitive shadow methods of determining time finally culminated in the sun-dial.

It must have been very early observed that the shadow cast by a vertical object, such as a tree, or a rock, or the like, changed its length and its direction in the course of a day and thus could be used to subdivide the day and measure time. The next step was almost an obvious one. A rod or staff placed vertically in the ground would be much better than a natural object, as its shadow would be much more definite and sharply defined and its length and position could be determined with much greater precision. Then a series of terraced steps were perhaps arranged about the rod or stones were placed in suitable positions so that the length and direction of the shadow could be better observed and, behold! a primitive sun-dial was in existence. These early sun-dials were without doubt large affairs and in no sense portable or even movable. In fact the obelisks and even the pyramids in Egypt may have been used for this purpose. When the sun-dial was first made portable it is impossible to say.

Finding the meridian. — The shadow cast by a vertical rod has been used for centuries, almost down to the present

time, for determining the meridian and the instant of true solar noon. It used to be a matter of importance; now it is only a matter of interest. A simple experiment will illustrate this. Take a smooth board and place on it a piece of paper. Attach a short vertical rod to the board and around its foot draw a series of concentric circles. Place the board in a horizontal position, facing the south, on a day when the sky is cloudless. Note carefully the points where the tip of the shadow crosses the various circles both in the forenoon and in the afternoon. Then bisect these various arcs and draw a line as nearly as possible through all these mid-points. This line will be the meridian, and the instant when the shadow of the rod is on this line will be true solar noon. All this is shown in Fig. 15. By noting carefully the location of the board, it may be replaced any subsequent day in the same position and the time of true solar noon determined. The determination will probably not be in error by more than a few minutes. Many are the families that up to even fifty years ago had a "noon mark" on a south window sill or on the kitchen floor for telling time, sometimes even for correcting their clocks.

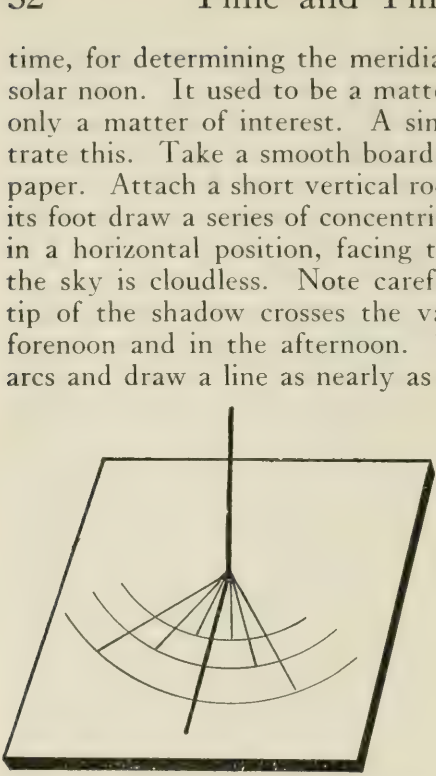


FIG 15. — BOARD WITH VERTICAL ROD FOR FINDING THE MERIDIAN AND TRUE SOLAR NOON.

The simplest possible sun-dial. — Before taking up the history of the sun-dial it will be well to notice the appearance and construction of the simplest possible, modern, portable sun-dial. Such a dial is pictured in Fig. 16. It consists of a rectangular base which must be smooth and flat and placed in a horizontal position. On it are drawn the various dial lines, and these are numbered at their ends with the hours of the day. To this base is fastened the rod or

object which casts its shadow among the dial lines and thus indicates the time. This object is spoken of as the rod, or the style, or the gnomon. It may have any shape or size. The one indispensable condition is that the edge which casts the shadow must be parallel to the axis of the earth. This means that it must point to the north pole of the sky (see page 3). It also means that it must make an angle with the horizontal base which is equal to the latitude of the place, for in all books on Astronomy it is demonstrated and much emphasized that the altitude of the north pole of the sky, that is its angular distance above the horizon, is

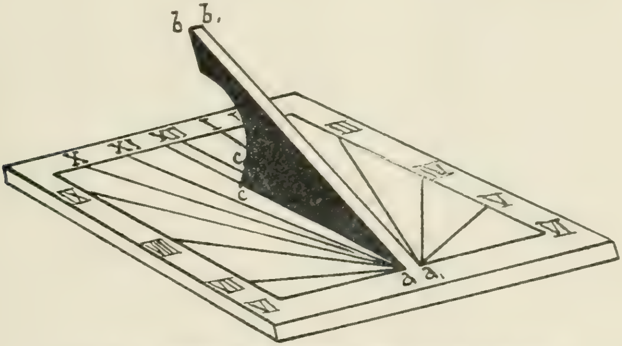


FIG. 16. — A SIMPLE, MODERN, PORTABLE SUN-DIAL.

equal to the latitude of the place. In the figure a triangular-shaped style is pictured. The edge which casts the shadow during the morning is the line ab; during the afternoon it is the edge a_1b_1. These two edges must both be parallel to the axis of the earth, otherwise the style may have any size or any artistic form which one wishes to give it. The one represented in the figure is easy to make and can be firmly attached to the horizontal base. Sometimes a circular level and a compass are attached to the dial so that, if it is moved about, it may be easily made horizontal and pointed in the right direction. The base can, of course, be circular as well as rectangular and the material may be either wood or brass.

It might naturally be supposed that the various dial lines make the same angle with each other. This is not the case, and furthermore their position depends upon the latitude of the place, so that a dial constructed for one place is not correct for another of a different latitude. Both the angle of the style and the position of the dial lines must be correctly determined for the place in question. This cannot be too strongly emphasized, as some makers of modern sun-dials set the gnomon correctly for the latitude of the place, but the dial lines are the same for all. They have been constructed for an "average latitude." Such dials are much cheaper to make and are generally not far out of the way, but in extreme cases an error of many minutes of time may result. Simple brass sun-dials may be purchased for \$10 or even a little less. A good brass sun-dial of suitable size and artistic appearance constructed for the latitude of the place will cost \$25 and up. If of larger size and more elaborate form and with a pedestal the price will, of course, be larger. In New York City sun-dials may be procured at Wanamaker's, Broadway and 10th St., or of E. B. Meyrowitz, 237 Fifth Avenue.

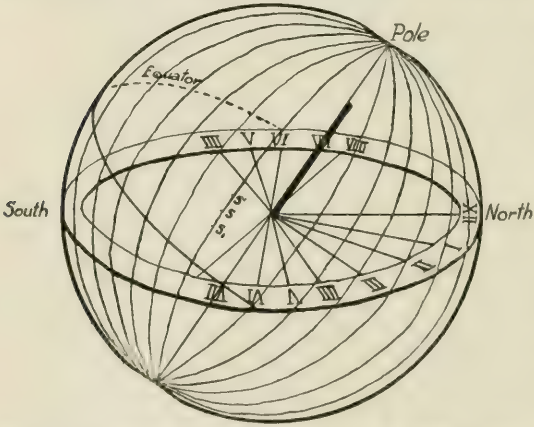


FIG. 17. - ILLUSTRATING THE RELATION OF THE SUN - DIAL TO THE SUN.

The next natural question to ask is why it is so very important that the shadow-casting edge should be parallel to the earth's axis. The answer is this: if the style is parallel to the earth's axis, then the dial is correct for all times of the year, both winter and summer. If it has any other position whatever, then the dial, strictly speaking, is cor-

rect for only two days of the year, and only approximately correct for the rest of the time. The reason for this is of course to be found in the sun which, as every one knows, migrates north and south in the course of the year, being high in summer and low in winter. The accompanying figure (see Fig. 17) will make clear why a dial with its style parallel to the earth's axis is independent of the sun's migration and will also illustrate the general relation of a sun-dial to the sun's position on the face of the sky. The sphere represents the face of the sky. It will be seen that when the sun is on the circle $PS'SS_1$ the shadow of the style will fall along the VIII line, and this will be independent of the fact as to whether the sun is at S or S' or S_1.

The history of the sun-dial. — At the beginning of this chapter it was stated that that ancient and interesting invention, the sun-dial, originated in Babylonia at least as early as 2000 B.C. From there the knowledge of it spread to all parts of the world — to India and China, to Egypt and Palestine, and eventually to Greece and Rome.

The first mention of a particular sun-dial is in the eighth verse of the thirty-eighth chapter of Isaiah. "Behold, I will bring again the shadow of the degrees, which has gone down in the sun-dial of Ahaz, ten degrees backward. So the sun returned ten degrees, by which degrees it was gone down." In the Revised Version the word steps is used instead of degrees. "Behold, I will cause the shadow on the steps, which is gone down on the dial of Ahaz with the sun, to return backward ten steps. So the sun returned ten steps on the dial whereon it was gone down." A great deal has been written on the probable or possible form of this sun-dial, but the fact still remains that we have no definite information. It probably consisted of a vertical shadow-casting rod, perhaps surrounded by a flight of steps. The date of the reign of Ahaz is a little earlier than 700 B.C.

Herodotus says: "It was from the Babylonians that the Greeks learned concerning the pole, the gnomon, and the twelve parts of the day." Vitruvius in his *de Architectura* mentions first of all the sun-dial of Berosus, the Chaldean.

Now the date of Berosus is uncertain. Some would assign him to the tenth or even eleventh century B.C. If this is true he may have been the first to introduce a sun-dial into Greece. Others would make him as late as the second or third century B.C. If this is true, it must have been a special form of the sun-dial, the "hemicyclium," which he introduced. Perhaps the discrepancy in the dates can be accounted for by the fact that there may have been more than one Berosus. At any rate the sun-dial was known in Greece as early as 400 or 500 B.C., and in later times increased greatly in the number and variety of its forms.

The vertical rod still continued to be used. In fact the length of a man's shadow was frequently used. Appointments were made at a time when a man's shadow would be a certain number of times the length of his own foot.

The hemicyclium ascribed to Berosus seems to have been one of the favorite forms. Vitruvius describes it as follows: "The semicircular form, hollowed out of a square block, and cut under to correspond to the polar altitude."

Fig. 18 illustrates its theoretical appearance. The gnomon was usually horizontal, although it may have been perpendicular to the sloping front face. It probably consisted of an iron rod carrying at its end a small sphere. In the first case the sun-dial would indicate those so-called temporary hours of unequal length into which the Greeks divided the day time regardless of its length (see page 8). In the second case the gnomon would be parallel to the earth's axis, as this front face was supposed to be in a plane parallel to the plane of the equator. The dial would thus indicate correct true solar time for all times of the year. In fact the time of year could be roughly indi-

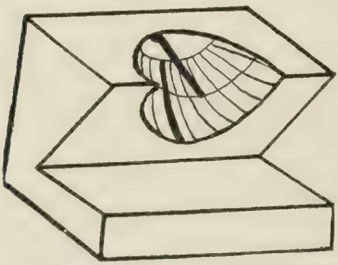


FIG. 18. — THE PROBABLE APPEARANCE OF THE HEMICYCLIUM.

cated by the dial with the gnomon in either position. The tip of the shadow would come forward the largest amount on June 21, when the sun was highest and the least amount on December 21, when the sun was lowest. The three lines drawn across the hour lines would represent the path of the tip of the shadow on June 21, on December 21, and when halfway between, that is on March 21 or September 21. Fig. 19 pictures such a dial without the gnomon, which was found at the foot of Cleopatra's Needle by J. Scott Tucker in 1852, and is now in the British Museum. Greek letters were used instead of numbers to indicate the hours.

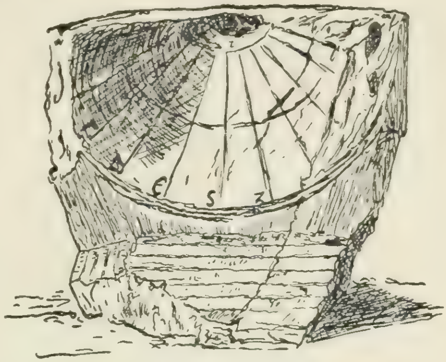


FIG. 19. — THE HEMICYCLIUM FOUND AT THE FOOT OF CLEOPATRA'S NEEDLE.

The statement is often made that the Romans learned of sun-dials from the Greeks. There is, however, no positive proof of this. The first sun-dial mentioned at Rome was one placed by Papirius Cursor in the court of the Temple of Quirinus in 293 B.C. The second Roman sun-dial was one brought by Valerius Messala during the First Punic War from Catania in Sicily. The number of dials in Rome must have increased very rapidly until they were practically everywhere. Aulus Gellius, in Chapter 3, Book 3, quotes some lines which he ascribes to Plautus. An English translation is as follows:

> "The gods confound the man who first found out
> How to distinguish hours — confound him, too,
> Who in this place set up a sun-dial,
> To cut and hack my days so wretchedly
> Into small pieces! When I was a boy,
> My belly was my sun-dial — one more sure,
> Truer, and more exact than any of them.

This dial told me when 'twas proper time
To go to dinner, when I ought to eat;
But, now-a-days, why even when I have,
I can't fall to, unless the sun gives leave.
The town's so full of these confounded dials,
The greater part of its inhabitants,
Shrunk up with hunger, creep along the street."

Plautus died in 184 B.C., so that sun-dials must have been very common in his time. Vitruvius, who probably lived several centuries later, says in Chapter VII of Book IX of his *de Architectura* (Morgan's translation): "For I cannot invent new kinds myself at this late date nor do I think that I ought to display the inventions of others as my own." He mentions twelve or more different kinds of dials, among them one which can be hung up by the traveler.

At the present time one almost never sees the remains of a Roman sun-dial in connection with Roman ruins and there are extremely few in the Museums. The marvel is how completely they were all destroyed.

During the early Middle Ages sun-dials continued to be fairly common, although very few of them have been preserved to the present day. In England there are a few dating from Anglo-Saxon times. They were often of stone and quite elaborately carved. In fact when of intricate construction and costly material they were considered suitable presents for kings and monarchs. They were found on monasteries and cathedrals. They were found on public buildings and in the court yards of castles. They were found on street corners and in public squares. They were of many forms, sizes, and kinds. Some were placed on pillars. Others were attached to the walls of buildings. Some were portable.

During the sixteenth and seventeenth centuries much greater interest was taken in the theory and construction of sun-dials and many books appeared on dialing or the art of making sun-dials. Most of the old sun-dials which are still preserved in their former places have been constructed during the last three centuries. Four of these are pictured in

Figs. 20 to 23. The first one is on the famous cathedral at Chartres in northern France and carries the date 1578. The second is in the yard of Corpus Christi College at Oxford, England. This college was founded in 1516 and the sun-dial dates from 1581. The third is "am Turme des Edelsitzes Liebenegg" near Innsbruck and dates from 1601. The fourth is on the church at Loschwitz near Dresden and dates from 1708.

FIG. 20.—THE SUN-DIAL ON THE CATHEDRAL AT CHARTRES IN NORTHERN FRANCE, DATING FROM 1578.

In the sixteenth and seventeenth centuries when watches had become small enough to be carried in the pocket, sun-dials were also made so small that they could be carried easily. The ring form was perhaps the commonest. This was held vertical and in the plane of the sun by means of the small ring at the top. The sun shining through a small opening cast a spot of light on the ring opposite and by its position indicated the time. The hole was carried by a slide which could be

FIG. 21. — THE SUN-DIAL IN THE YARD OF CORPUS CHRISTI COLLEGE AT OXFORD, ENGLAND.

FIG. 22. — THE SUN-DIAL "AM TURME DES EDELSITZES LIEBENEGG," NEAR INNSBRUCK, DATED 1601

(From LÖSCHNER, *Sonnenuhren*.)

moved up or down. This was necessary in order to make the dial correct for different times of the year. The months were usually indicated so that the hole could be quickly set to its proper position for the date in question. Another form had a hinged style and an attached compass for setting it in the right direction. Fig. 24 illustrates one of this kind. It is a silver pocket sun-dial, French, eighteenth century, Lucas maker, and is now in the Metropolitan Museum at New York. A third form was the "ivory book" form. It consisted of two tablets hinged together so that when open one was vertical and the other horizontal. They were connected by a string which acted as the shadow-casting gnomon. These were usually quite elaborate, having not only vertical and horizontal dials but secondary dials and other astronomical devices as well. But few of these are to be found in museums. Two, which are now in the Metropolitan Museum of Art in New York City, are pictured in Figs. 25 and 26. It should be mentioned here that this museum possesses an extremely good collection of portable sun-dials. The first one was made by Hanns Troschel in 1620 and is so inscribed at the bottom of the vertical tablet. This

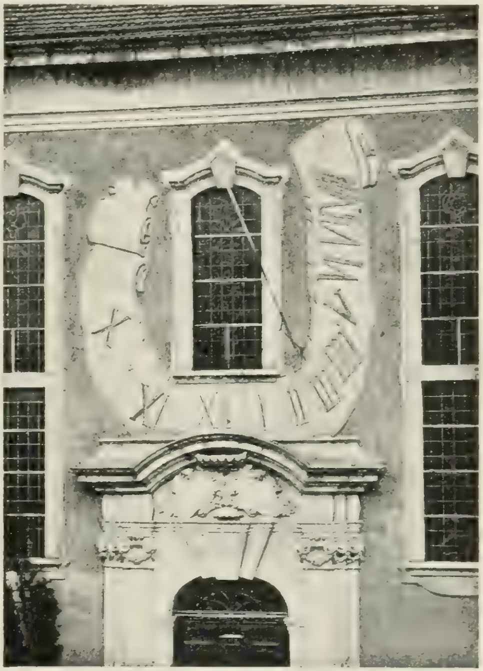


FIG. 23.—THE SUN-DIAL ON THE CHURCH AT LOSCHWITZ NEAR DRESDEN, DATED 1708.
(From LÖSCHNER, *Sonnenuhren*)

FIG. 24. — A POCKET SUN-DIAL WITH A HINGED STYLE.

(French — Eighteenth Century — Lucas, Maker.)

FIG. 25. — AN IVORY BOOK SUN-DIAL.

FIG. 26. — AN IVORY BOOK SUN-DIAL.

FIG. 27. — A SMALL CYLINDER SUN-DIAL, SOMETIMES CALLED THE SHEPHERD'S SUN-DIAL.

tablet also contains the chief vertical dial and a secondary one at the top for indicating the signs of the zodiac and the length of the day. The lower tablet contains the compass, the horizontal dial surrounding it, and a secondary dial. In the one illustrated in Fig. 26 the lower tablet is margined with the hours, and this is the chief dial. The lower tablet also contains the compass and a concave secondary dial. The upper tablet contains a list of places with their latitudes. Above this are two musicians and two lovers and above these two secondary dials, one having the signs of the zodiac.

There are also other quite small portable dials which are of late invention. Two of these, the card and string dial and the little cylinder dial, can only be mentioned in passing. One of the latter form in the possession of the author is illustrated in Fig. 27.

To-day sun-dials are not seen as often as they should be. They have ceased to be important and are only interesting and instructive. At present new, modern ones are found in public parks, on college campuses, or in the gardens of elaborate country estates.[1] Old ones have been renovated and replaced and are venerated on account of their historic associations.

The largest sun-dial ever built is at Jaipur, India. It was erected in 1730 by Jai Singh II, Maharaja of Jaipur, and restored in 1902. The gnomon is 147 feet long and 90 feet high. The shadow falls on a great stone arc having a radius of 50 feet. The shadow moves about a foot in five minutes.

Mottoes. — Many sun-dials, particularly those of the last two or three centuries, had appropriate mottoes placed

[1] Very recently the Ansonia Clock Co. has put out a small, good looking, thoroughly scientific, inexpensive pocket sun-dial. It has a compass with the variation marked so that the dial may be correctly placed. The style may be elevated to the proper angle. There are three sets of dial lines for latitudes 35°, 40°, and 45°. There are two tables in the cover. One gives the equation of time for various dates. The other gives the latitude, longitude, and variation for different cities. True solar time may be observed within five or ten minutes and mean solar and standard time can be readily computed. It sells for \$1.00 or a little more.

on them. Some of these mottoes are crude witticisms. Many give admonitions and good advice. A few taken from the *Book of Sun-dials* by Mrs. Gatty are given as illustrations:

ASPICIENDO SENESCIS.
Thou growest old in beholding.

CARPE DIEM, HORA ADEST VESPERTINA.
Seize the present moment, the hour of eve is nigh.

È DI FERRO LO STIL: MA È D'ORO IL TEMPO.
The style is iron; but time is gold.

HORAM SOLE NOLENTE NEGO.
The hour I tell not, when the sun will not.

LUMEN ME REGIT, VOS UMBRA.
The light guides me, the shadow you.

NON REGO NISI REGAR.
I rule not if I be not ruled.

NOS EXIGUUM TEMPUS HABEMUS, SED MULTUM PERDIMUS.
We have little time, but we waste much.

Dialing or gnomonics, as it is sometimes called, is the art of making a sun-dial. It is considered by some a most interesting and intellectual avocation, as it calls to its aid Astronomy, Geography, Geometry, Mathematics, Mechanics, Architecture, and Art. The general case would be: given a style having any direction whatever and a surface, plane, cylindrical, or spherical, sloping in any direction, to construct the dial lines for the various hours. The simplest possible case would be: given a style parallel to the earth's axis and a plane, horizontal surface, to construct the dial lines. This last is the only one that will be considered here. In fact the problem is to construct the dial pictured in Fig. 16. Such a dial would probably be made of wood, although it might be made of brass or even of stone or cement. The beginner would surely choose wood and the construction of such a sun-dial is heartily recommended to all those who like to make things with their hands. First choose the base board. A good size is about 10 by 15 inches, although it may be made larger or smaller to suit one's taste. It must be made truly rectangular and nicely smoothed and fin-

ished. The best length (*ac* in Fig. 16) for the style board is about one half the length of the base board. In thickness three quarters of an inch is good. The height *cb* is fixed by the latitude of the place. It must equal the length of the base *ac* multiplied by a factor taken from the accompanying table for the latitude of the place. Those familiar with Trigonometry will see that the factor is nothing

Latitude	Factor or Tan Latitude	Latitude	Factor or Tan Latitude	Latitude	Factor or Tan Latitude
25°	0.466	35°	0.700	45°	1.000
26	0.488	36	0.727	46	1.036
27	0.510	37	0.754	47	1.072
28	0.532	38	0.781	48	1.111
29	0.554	39	0.810	49	1.150
30	0.577	40	0.839	50	1.192
31	0.601	41	0.869	51	1.235
32	0.625	42	0.900	52	1.280
33	0.649	43	0.933	53	1.327
34	0.675	44	0.966	54	1.376

more or less than the tan of the latitude. Thus if the base *ac* has been made 8 inches, the height *cb* must be 8×0.839 or 6.71 inches for a place in latitude 40°. In this way construct a suitable style for the dial. It may be carved or decorated to suit one's taste. It should be fastened firmly to the middle of the base board about 3 inches back from the edge. Screws put through from the under side of the base board make a very good and easy way of securing it.

The next is the chief problem, namely, to lay out the dial lines. This may be done in two ways. The angle which each line makes with the XII line may be computed and then laid off with a protractor. This is recommended to those who like mathematical formulae and love a logarithm table, and the necessary formula will be given later. The second way is to determine the location of the lines graphically and most people will probably prefer this method. Take a piece of drawing paper or any large sheet of white paper and fasten it to a drawing board or any smooth table top. Through the middle of it draw two parallel lines sep-

arated by a distance equal to the width of the style. Fig. 28 shows what will eventually appear on this drawing paper. The two parallel lines are aK and a_1K_1. Mark two other points L and L_1 at any suitable distance from a and a_1. Ten inches is a good distance to choose. Mark two other points M and M_1 at such a distance from L and L_1 that aL

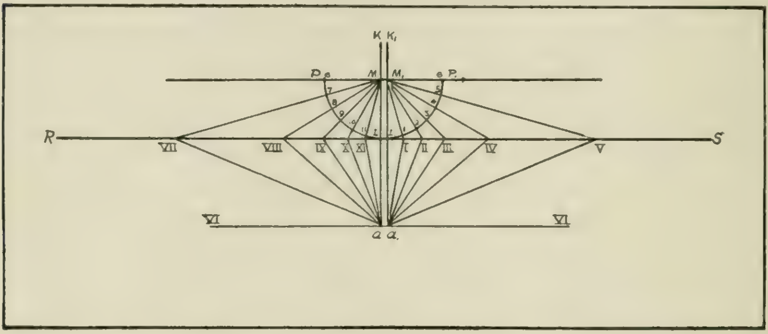


FIG. 28. — THE METHOD OF CONSTRUCTING THE DIAL LINES.

times a factor will equal LM and a_1L_1 times the same factor will equal L_1M_1. The factor must be taken from the table given below for the latitude of the place. Those knowing Trigonometry will again notice that this factor is the sin of the latitude. Thus if aL has been made 10 inches and the latitude is 40°, then LM must be 10×0.643 or 6.43 inches. About M and M_1 as centers describe quadrants with ML and M_1L_1 as radii. Draw RS through

Latitude	Factor or Sin Latitude	Latitude	Factor or Sin Latitude	Latitude	Factor or Sin Latitude
25°	0.423	35°	0.574	45°	0.707
26	0.438	36	0.588	46	0.719
27	0.454	37	0.602	47	0.731
28	0.470	38	0.616	48	0.743
29	0.485	39	0.629	49	0.755
30	0.500	40	0.643	50	0.766
31	0.515	41	0.656	51	0.777
32	0.530	42	0.669	52	0.788
33	0.545	43	0.682	53	0.799
34	0.559	44	0.695	54	0.809

LL_1 perpendicular to these parallel lines. Mark off on the arcs LP and L_1P_1 $15°$ spaces. That is, divide the arcs LP and L_1P_1 into 6 equal parts, numbering them as shown in the figure. Through these points draw lines from M and M_1 to the horizontal line RS. Connect a and a_1 with these points on RS and the dial lines as numbered have been determined.

The next step is the purely mechanical one of transferring the lines to the dial itself. The simplest way is to cut the drawing along the lines aL and aVI and along a_1L_1 and a_1VI and then place the pieces on the dial in the proper position. The outer portions of the drawing may have to be cut away so that only the beginnings of the lines will show. The lines can now be drawn on the dial itself. The rest is just a matter of finishing and only two or three suggestions will be given. If the dial is to be put out of doors much, it is well to use a varnish which will stand water. Brass tack numerals can be easily obtained to mark the hours on the dial. The mathematical theory that the dial lines are thus correctly constructed is too complicated to be given here. It is well given in Jacoby's *Astronomy* and several other books. For those who might like to compute the angles which the various dial lines make with the XII line, the necessary formula is given without proof. It is

$$\tan A = \tan t \sin \phi.$$

Where A is the angle desired, t is $15°$ for the I and XI o'clock lines, $30°$ for the II and X o'clock lines, etc., and ϕ is the latitude of the place.

The methods of constructing dials when the surface is not horizontal or when it is spherical or cylindrical or when the style is not parallel to the earth's axis are naturally much more complicated. The simplest cases and those usually treated are (1) when the surface is perpendicular to the earth's axis; (2) when the surface is vertical and faces east, south, or west; (3) when the surface is parallel to the earth's axis. For these methods the reader must be referred to other books. In Appendix V the literature on sun-dials is treated.

CHAPTER III

THE CLEPSYDRA AND OTHER EARLY TIMEKEEPERS

The origin of the clepsydra. — In the previous chapter it was stated that the sun-dial was historically the first timekeeper to be used. The second in chronological order was the clepsydra, or the Greek water clock.[1] The statement is often made that the clepsydra was invented by Ctesibius at Alexandria in the second century B.C. Vitruvius says of him: "Methods of making water clocks have been investigated . . . first of all by Ctesibius the Alexandrian, who also discovered the natural pressure of the air and pneumatic principles. . . . Preëminent for natural ability and great industry, he is said to have amused himself with ingenious devices." The date is, however, altogether too late for the first introduction of the water clock. It must have been a special kind which Ctesibius invented.

The water clock may have come from Babylonia along with the sun-dial, and some even claim for it an equally great antiquity. It may have originated in Egypt. It was used very early in India and China, but may have been independently discovered in these countries. It is stated by Pliny in his *Historia Naturalis* that Scipio Nasica brought it to Rome from Greece in 157 B.C. Later it came into great favor with both the Greeks and Romans. Vitruvius devotes about eight times as much space in his book on architecture to the water clock as to the sun-dial. This can hardly represent, however, in his mind the relative importance of the two timekeepers.

During the early Middle Ages water clocks continued to be used and were often very elaborate, but they did not remain in favor as the sun-dial did. During the seven-

[1] From the two Greek words κλέπτειν (kleptein), to steal, and ὕδωρ (hudor), water.

teenth century there was a slight increase in their popularity. At the present time they are never seen and, in fact, there are very few of them, even in large museums.

The various forms of clepsydras. — The simplest and perhaps earliest clepsydra consisted of an earthen vessel with a small hole in the bottom. This was filled with water up to a certain mark and the water was allowed to trickle out of the hole. It would empty itself in approximately the same intervals of time. It was perhaps used for limiting the length of public speeches and the like. In fact there are quite a few references in Greek and Roman writings which would indicate this to have been a fact. Another simple form consisted of a basin from which the water trickled drop by drop into a receiving vessel which had marks on its inside to indicate the various hours.

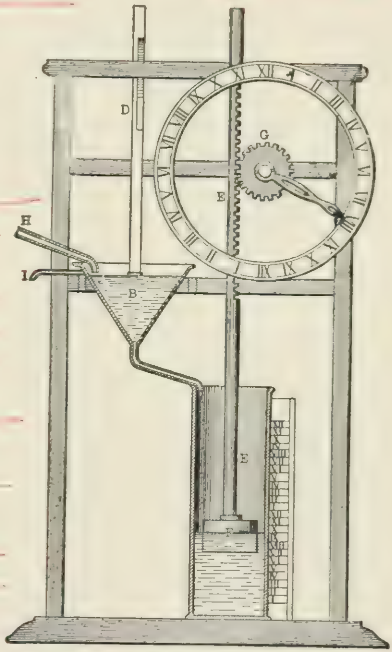


FIG. 29. — A COMMON FORM OF CLEPSYDRA IN GREEK AND ROMAN TIMES.

A similar device was often used in India. A brass, hemispherical bowl with a small hole in the bottom was floated on a larger vessel of water. In time this would fill and sink. The bowl was then recovered, emptied, and set floating again. The attendant whose duty it was to reset the bowl then struck the hour, perhaps on the bowl itself. This device would be fairly satisfactory, provided the attendant was.

A really mechanical clepsydra is illustrated in Fig. 29. Water is freely supplied by a pipe *H* to the conical vessel *B*. From a small opening in the bottom of this vessel it

drops into a large reservoir *F*. In order to have the rate of flow uniform, the water must remain at the same level in the conical vessel *B*. To accomplish this, water is supplied in excess and the overflow escapes through a side pipe *I*. As the water collects in the reservoir *F* a float is raised and to this is attached a rod *E* with cogs. These fit into a cogged wheel *G*, to which the hand is attached, which moves over the dial. When the reservoir becomes full, it must be emptied and the clock reset. This kind of clock was not suited to the Greek custom of having hours of unequal length, often called temporary hours. It will be remembered that it was their custom to divide the day and the night into twelve hours each. Thus in summer the day hours would be much longer than the night hours and in winter the converse would be true. Only on March 21 and on September 21 would the day hours and the night hours have the same length. In order to have a clepsydra subdivide the day and the night after this fashion, it is necessary either to change the rate of flow of the water or to change the dial. In the clepsydra just described there is a device for changing the rate of flow of the water. Inside the conical vessel *B* there is a conical stopper to which is attached a rod *D*. By raising this, the flow of water is increased and by lowering it the flow is made less. This rod can be easily graduated so that it could be quickly set for day or for night or adjusted for any time of year.

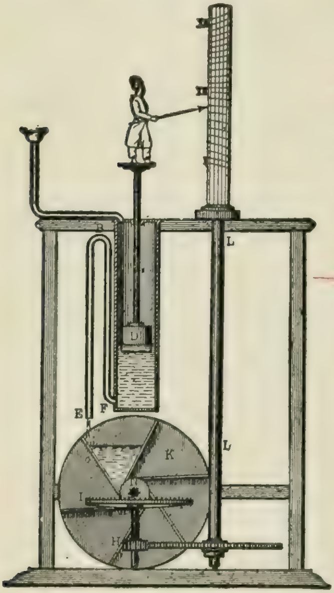


FIG. 30.—A CLEPSYDRA INDICATING UNEQUAL OR TEMPORARY HOURS.

In Fig. 30 is shown a clepsydra, probably very similar to the one invented by Ctesibius, in which the flow of water

remains uniform, but the dial has been modified. As the water collects in the reservoir a float is raised as before. On this float is a figure carrying a wand and pointing out the hours on the surface of the cylinder. The hour lines on this cylinder are not horizontal but slope in such a way that the wand passes over just twelve hours during both the day and the night. This cylinder must be turned and set for each day in the year.

Some clepsydras were provided with a device for emptying the reservoir automatically when it became full. Such a device, which is nothing more or less than a siphon, is shown at *F*, *B*, *E* in Fig. 30. When the reservoir became full up to the top of the short arm of the siphon, it would immediately be emptied. The turning of the cylinder containing the hour lines was also often accomplished automatically. One device was to allow the float in rising to push on a lever and thus turn the cylinder one cog. Of course there must be 365 cogs on the rim of the cylinder. Another way (shown in the figure) of turning the cylinder was to allow the water escaping from the siphon to do the work.

Development of the clepsydra. — As the centuries passed the water clock developed in two ways. In dry countries sand was substituted for water. In fact it is sometimes claimed that this took place in Roman times and that the sand-glass is as old as the clepsydra. The invention of this device is usually ascribed to Luitprand, a monk of Chartres, who lived in the eighth century. Of course sand could not raise a float, but by collecting in the reservoir, the time could be indicated by its height. It also possessed some advantages. It would not freeze, it would not evaporate, a new supply was never needed, it would run at a regular rate always. Later, when glass began to be made and proficiency was acquired in its use, the sand was inclosed in glass vessels to keep out the moisture and cause it to run freely. Still later the vessel holding the supply of sand and the reservoir were connected together, the air was more or less exhausted, and the whole apparatus was hermetically

sealed. In this way the modern sand-glass, or "hour-glass," developed from the clepsydra.

From the sixteenth century on the hour-glass was fre-

FIG. 31. - A SET OF FOUR SAND-GLASSES MADE DURING THE FOURTEENTH CENTURY.
(The National Museum, Washington.)

quently used in churches to limit the length of sermons. But the preacher frequently turned the glass!! In Navigation the 28-second sand-glass has been used until very recent

times for determining the number of "knots per hour" covered by a vessel. In Fig. 31 is shown a set of four sand-glasses probably made at Nürnberg during the fourteenth century. They are now in the National Museum at Washington.

The second development of the clepsydra is the one in which we are chiefly interested. As the years passed it became very complicated. Not only was a hand moved over a dial but a great variety of mechanical operations were performed. This had already commenced in the time of Ctesibius, for Vitruvius says of him: "Other racks and other drums, similarly toothed and subject to the same motion, give rise by their revolution to various kinds of motions, by which figures are moved, cones revolve, pebbles or eggs fall, trumpets sound, and other incidental effects take place." Centuries later clepsydras must have become very complicated machines.

In 807 A.D. a clepsydra of bronze and gold was given to Charlemagne by the King of Persia, Haroun-al-Raschid. "The dial was composed of twelve small doors, which represented the hours; each door opened at the hour it was intended to represent, and out of it came the same number of little balls, which fell one by one, at equal intervals of time, on a brass drum. It might be told by the eye what hour it was by the number of doors that were open, and by the ear by the number of balls that fell. When it was twelve o'clock twelve horsemen in miniature issued forth at the same time and shut all the doors." The chief point to notice is that elaborate mechanism, trains of cogged wheels, and the like, began to be associated with these water clocks and this has made the water clock the ancestor in the direct line of modern clocks.

Other early timekeepers. — Two other early timekeepers should be mentioned. These are notched candles and graduated lamps.

A candle always made of the same material, of the same size, and with a wick of the same material and size burns very nearly the same number of inches each hour. This

fact was made use of in timekeeping, particularly in monasteries. Notches or marks were placed on candles at such a distance apart that a certain number of spaces would burn each hour. They thus served in a rough way to keep the time and subdivide the day. It is narrated that King Alfred, who reigned from 872 to 900, was especially fond of this form of timekeeper. In fact a candle can be used as an alarm clock. The story is told of Alpine guides who stick a pin in a candle and attach a shoe to it by means of a string. When the candle burns down to the pin, the shoe falls to the floor and the climbers are awakened.

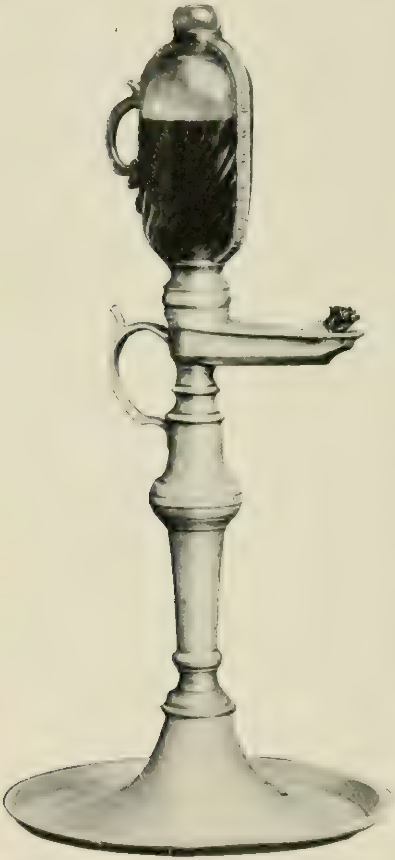


FIG. 32. — AN EARLY LAMP TIMEKEEPER
(The National Museum, Washington.)

A lamp with a graduated oil vessel, as shown in Fig. 32, would also serve as a rough timekeeper. A few of these "curiosities" are still to be met with in museums. The one shown is of pewter and was collected in Nürnberg. It is now in the National Museum at Washington.

CHAPTER IV

THE HISTORY OF CLOCKS TO 1360

Introduction. — This chapter covers four centuries in the history of clocks — from 960 A.D. to 1360 A.D. These are not random dates, but both were chosen for a definite reason. In 960 A.D. the mechanical clock had certainly not made its appearance. The only timekeepers were clepsydras, sand-glasses, and sun-dials. Possibly the notched candle or its twin brother, the graduated lamp, were occasionally used. In 1360 A.D. at least one clock in the modern sense of the word was in existence. It was a self-contained, purely mechanical, weight-driven, verge-controlled timekeeper. Such was the clock made about this time[1] by Henry Wieck, or Henry De Vick, as he was afterwards called, of Würtemberg for Charles V of France. It was placed on the Royal Palace, which is now the Palais de Justice in Paris. Its position may have been changed; at any rate its present architectural surroundings date from 1585, but it was an unquestioned mechanical clock in the modern sense of that term and its construction is accurately known. A description of it has come down to us from the famous Julien Le Roy (born 1686, died 1759), who examined it while it was still in running order and in its original condition.

Very little can be definitely stated about the history of clocks during these four centuries. It is impossible to name with certainty the person who first invented the clock, if, indeed, it was invented by any one person. More likely it was a gradual development. There are naturally two sources of information. There are in the first place remnants of these early clocks which have been preserved until the present time. The great difficulty here is that these

[1] This date is variously given as 1360, 1364, 1370, and 1379 by different writers.

early clocks have been so often rebuilt and later improvements have been added. Some now have pendulums, but the pendulum was not invented until a good three centuries after this time. Thus in connection with these old clocks it is almost impossible to say, even when the works or a part of them are still in existence, what the original form and construction were. The second source of information consists of the descriptions of and references to these early timepieces in old documents. But the descriptions are usually very scanty and insufficient and they ordinarily refer to what the clock did and not to its construction. Furthermore, the descriptions are usually in Latin and the word used for clock is "horologium." Now horologium is a general word and one applied to all kinds of timekeepers, including both clepsydras and sun-dials. Thus when the statement was made that in a certain year a certain person constructed a "horologium," it is impossible to know whether it was a clepsydra, a sun-dial, or a real mechanical clock. The word *horologium* should be translated timekeeper or by the old, now nearly obsolete, English word horologe. The word clock really signifies *bell*, and comes from the Latin *glocio* by way of the old French or the Low Latin *cloca* or *clocca*. It is akin to the Saxon, *clugga*, the Anglo-Saxon, *clocge*, the German, *Glocke*, and the French, *cloche*. Originally it was the striking of the clock which was the all-important thing and which eventually named the timekeeper. The word has of course outgrown its original significance.

One thing was certainly true of these early clocks. They were all very large. Large, in fact, is too mild a word; they were ponderous affairs. They were in no sense portable or even movable. The parts were not of fine and delicate construction, but were usually hammered out in a blacksmith's shop.

Since the *definite* history of these four centuries cannot be written, it may be interesting to have a *hypothetical* history of them. Thus in what follows there will be given first a reasonable and plausible way in which the clock *may*

have developed. After that the scanty information which we possess about some of the early clocks belonging to this period will be given.

The hypothetical history of clocks. — It was stated in the previous chapter that the clepsydra was the ancestor in the direct line of the modern clock. As the centuries passed, the clepsydra had become more and more elaborate and intricate. Not only did a hand move over a dial, but the hour was struck, cocks crew, lions roared, drums were beaten, and various motions were executed by small figures. All this required elaborate mechanism — trains of cogged wheels, levers, and the like. The point to emphasize is that mechanism in connection with clepsydras had become elaborate and intricate.

But the clepsydra at best was an unhandy timekeeper. In dry countries and in many other places where a timekeeper was desired, there was no flow of water available. To bring it by hand required too much time and attention. Thus a weight was substituted for water as the driving power and a great step forward had been taken. But the use of the weight brought new complications and difficulties. There was no means of keeping it from driving the clockwork too fast. In the first weight clocks the speed was probably kept down simply by friction. An attendant would wind up the weight and then it would run down as fast as the friction of the clockwork would allow it to. It would perhaps be arranged to run down in just an hour. Thus the attendant would strike the appropriate hour every time he wound the clock. A little later a fan-fly was probably added to increase the friction and thus allow the clock to run more slowly and regularly. A fan-fly consists simply of a fan, usually with two blades, which beats against the air and thus prevents a clock from running too fast. Fan-flies are still to be found for other purposes in modern clocks. One is nearly always attached to the striking mechanism to prevent the hours from being struck too rapidly. Such a device attached to the striking mechanism of a modern clock is shown in Figs. 205 and 206. A fan-fly attached

to an old movement is shown in Fig. 39. They are also sometimes attached to the escape wheel to keep it from striking too hard against the stop.

FIG. 33. — THE JACKS AT DIJON.
(From Dubois, *Histoire de l'Horlogerie.*)

As soon as a fan-fly was added, the clock required less attention from the attendant. It needed winding perhaps only once in three or four hours. It was therefore arranged so that the clock would strike the hour for itself. This required no new invention, as striking mechanisms were already in existence in connection with clepsydras. The actual striking was perhaps done in the first place by jointed automatons known as "Jacks." In Fig. 33 are shown the jacks at Dijon. These were formerly at Courtrai, which in the early part of the fourteenth century possessed a famous clock which struck the hours and was remarkable for its mechanism. It was said to have been the largest which had been made up to that time. In 1382, after the battle of Rosebecq, Philip, Duke of Burgundy, brought the clock with other spoils of war to Dijon and set it up in a tower of the church of Notre Dame. The figure of the child to strike the quarters was added in 1714.

The word jack is probably a shortening for Jaccomar-

chiadus, that is, a man in a suit of armor. It may have come from one Jacques Marck, a clock and lock maker of Lille. The date of the first introduction of jacks is unknown. In Fig. 34 is illustrated the old clock with jacks at York Cathedral in England. This clock, constructed during the reign of Edward IV (1461–1483), or earlier, was originally in the south transept. The dial was outside and the jacks inside. At present the dial and jacks are inside in the north transept near the choir aisle, as the illustration shows. The jacks are two dark oak figures popularly known as Gog and Magog. Other jacks in connection with old clocks may be seen in Figs. 38, 40, 309, 322.

FIG. 34. — THE CLOCK WITH JACKS AT YORK CATHEDRAL.

As yet these clocks had no dials. The word dial, by the way, comes from the Latin *dies* meaning *day*, because it indicated the divisions of the day. The hours and possibly the quarters were struck on bells. This illustrates the derivation of the word clock. The early towers where these clocks were usually placed were not constructed to leave a space for dials. But the desire for dials must have become steadily greater and finally they began to be added to clocks. This again was no new invention, as dials were known in connection with clepsydras. At first there was

only one hand — the hour hand. Later the minute hand was added, but probably not until long after 1360. And there was no need of one, for the clock of 1360 did not keep time much nearer than two hours a day!

But the clock as yet was a very imperfect mechanism. There was nothing but the fan-fly to keep it running at a regular rate. An attendant was constantly needed. And the rate of running must have been very irregular. If the oil gradually thickened, or there was a change in temperature, the rate of running of the clock must have changed tremendously. The crying need was for some device to so regulate the rate of running of the clock as to render it uniform. This was finally invented and consisted of a foliot balance, verge, and crown wheel. De Vick's clock of 1360 had such an arrangement and thus can be considered a clock in the modern sense of the term. We do not know how much earlier it was invented or by whom. It is pictured and described in Chapter VI.

We now have a purely mechanical, self-contained, weight-driven, automatically regulated clock. The attendant ceases to be a necessity and passes off the stage, leaving this new wonderful mechanism to be the center of attraction. In fact it is stated that the interest and incredulity in connection with De Vick's clock was so great on the part of the people that a guard was set to make sure that the clock was really automatic and there was no secret clock keeper to look after the mechanism.

Early clocks and clockmakers. — *When was the mechanical clock invented?* Stow says: "This yeare, 606, dyed S. Gregory, surnamed the Great, being the third yeere of Focas, 59 Emperoure of the Romanes, and after him Sabinianus succeeded, being the 63 Pope: he commanded clocks and dials to be set up in churches to distinguish the houres of the day." These clocks must have been water clocks, for it was certainly too early for mechanical ones. From this time on clocks are frequently mentioned, but there is never any proof that they were mechanical clocks. In fact there are one or two vague references to clocks

before this time. *Who invented the mechanical clock?* The writers on this subject are not agreed and yet the larger number, if they favor any single person, concede the honor to Gerbert, a studious Benedictine monk, who afterwards became Pope under the title of Sylvester II (see Fig. 35). He constructed a clock for the cathedral at Magdeburg in 996. It is said of him by an old writer: "Magdeburg horologium fecit, illud recte constituens consideratâ per fistulam stellâ nautarum duce." He made a timepiece at Magdeburg, setting it by looking at the polar-star through a tube. There is really no proof that it was a mechanical clock and not a water clock. It is also interesting to note that more emphasis is laid on setting the clock right than on its construction. Other writers mention Boethius; Pacificus, Archdeacon of Verona; William, Abbot of Hirshaw; and also John Megestein of Cologne as the possible inventors of the mechanical clocks. The claims of all of them rest upon very small foundations.

FIG. 35. — GERBERT, WHO MAY HAVE INVENTED THE MECHANICAL CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

If all the old records were carefully searched and the vague statements in the books and manuscripts by the early writers were considered, references to perhaps twenty clocks would be found which were probably mechanical

and were in existence before 1360. About most of these very little is known, many have passed out of existence, practically all of them have been rebuilt and reconstructed so often that almost no idea of the original form and structure, particularly of the mechanism, can be formed.

One of the oldest of the timepieces was a horologe sent by the Sultan of Egypt to Frederick II of Germany in 1232. "It resembles internally a celestial globe in which sun, moon, and planets moved, being impelled by weights and wheels, so that they pointed out the hour, day and night with certainty." This would appear to be a mechanical clock, but perhaps the old writer, having in mind later clocks, was mistaken about its being "impelled by weights."

The three oldest clocks mentioned in England were at St. Paul's Cathedral, at Canterbury Cathedral, and in a former clock-tower of Westminster. In the accounts of St. Paul's for 1286 allowances to the clock-keeper, "Bartholomo Orologiario" are entered, namely, of bread at the rate of a loaf daily, for three quarters of a year and eight days, two hundred and eighty-one panes. This would indicate that there was a clock at St. Paul's earlier than 1286. There are also several later references to the clock-keeper. Before 1298 it had jacks, usually spoken of as "Paul's Jacks," to automatically strike the hours. In 1609 they are spoken of thus: "The Great Dial is your last monument; where bestow some half of the three score minutes to observe the sauciness of the Jacks that are above the Man in the Moon there; the strangeness of their motion will quit your labour." In 1344 a contract was entered into to supply and fix a dial. This contract was between the Dean and Chapter of St. Paul's and Walter the Orgoner of Southwark. It is written in unpolished French and carries the date Nov. 22, 1344. There is this later reference to the dial: "Somewhat above the stonework of the steeple, was a fair dial; for which there was order taken in the 18th of Edward III, that it should be made with all splendor imaginable. Which was accordingly done; having the image of an angel pointing to the hour both of the day and night." All this would seem

to indicate that there was no dial previous to 1344. An old writer furthermore says: "The dial was placed below the jacks, which were not ousted from office, but continued to strike the hour with their accustomed regularity."

The building of the present cathedral of St. Paul's was commenced in 1675. In October, 1700, the following notice appeared in a kind of newspaper called *The Affairs of the World:* "Mr. Tompion, the famous watchmaker in Fleet Street, is making a clock for St. Paul's Cathedral which it is said will go one hundred years without winding up; will cost 3,000 £ or 4,000 £; and be far finer than the famous clock at Strasburg." Nothing came of the project. The clock was constructed by Langley Bradley in 1708, at a cost of £300. This clock had two dials, one facing down Ludgate Hill, and the other looking towards the south side of the churchyard. It remained in good condition until 1892, when it was taken down. A good description of the clock is to be found in F. J. Britten's magnificent book: *Old Clocks and Watches and their Makers.* The bell upon which the hours were struck also had an interesting history. In 1700 when the cathedral was approaching completion, the commissioners purchased from the church wardens of St. Margaret's, Westminster, the celebrated Great Tom which formerly hung in the clock tower. This was recast by William Whiteman, but the new bell cracked and was recast by Richard Phelps in 1716. It was nearly seven feet in diameter at the mouth and weighed almost five tons. The quarters were struck on two small bells just below the hour bell. At present there is a four-dial modern tower clock in the right tower, as may be seen in Fig. 36.

About the first clock at Canterbury Cathedral almost nothing is known. Dart, in his history of the cathedral, mentions that a large clock was set up in 1292 at a cost of £30. It is also recorded that in 1316, Prior Henry de Estria bought five bells for Canterbury Cathedral, whereof one, weighing 8000 pounds, was called Bell Thomas, and was placed in the great clock-house.

Photo. Underwood & Underwood, London

FIG. 36.—THE MODERN TOWER CLOCK AT ST. PAUL'S, LONDON.

In 1288 a clock with some great bells was put up in the Palace Yard at Westminster. There is a tradition that it was paid for out of a fine of 800 marks imposed upon Sir Ralph de Hengham, Chief Justice of the King's Bench, who out of mere compassion lessened a fine which had been imposed upon a very poor man. This is probably only a tradition, but it is mentioned by several writers. In the latter half of the fourteenth century, about 1365, Edward III had a clock-tower of stone erected at Westminster, in the court yard opposite the Palace or Hall, and near the site of the present clock-tower of the Houses of Parliament. This is usually considered the second Westminster clock, and there are many references to the various keepers of the clock. This tower was destroyed some time after 1600. A writer in 1692 says: "We crossed the Palace yard, on the east end of which lay the relics of Westminster clock-house, in a confused heap." As has already been stated, the bell was sold in 1700 and recast to become the bell for St. Paul's Cathedral clock. The present magnificent clock on the Houses of Parliament is entirely modern. It was finished in 1854, put up in the tower in 1859, and set going in 1860. It is described and pictured in Chapter XVII.

There was a clock at Caen in 1314 located on a bridge of that city. It was a striking clock and made by Beaumont, a local clockmaker. Some, however, consider that the clock was of later date and very similar to De Vick's clock at Paris.

Exeter in Devonshire, England, is particularly famous for its old clocks and they are especially interesting because they have been so thoroughly investigated by Mr. John James Hall[1] of Wellington Road in that city. There must have been a clock at Exeter Cathedral as early as 1318, since in the patent rolls of the eleventh year of the reign of Edward II, 1318, there is a grant to Rob. Fitzwalter of lands in Pennington for the service of repairing the organ

[1] See "Two Famous Old Devonshire Clocks," *American Machinist*, Vol. XXXV, No. 1, p. 5, and *Horological Journal* (London), Vol. LV, Nos. 658, 659, 660, pp. 151, 166, and 187.

and the clock in the cathedral. There is no certain trace of this original clock. In 1480 a clock was presented to the cathedral by Bishop Courtenay, and the dial of this is still on the wall of the north transeptal tower. In 1760 some additional works were added to show the minutes and in 1885 the old movement was replaced by a modern one. The dial of this interesting clock is shown in Fig. 37, and the following concise description is due to the kindness of Mr. Hall:

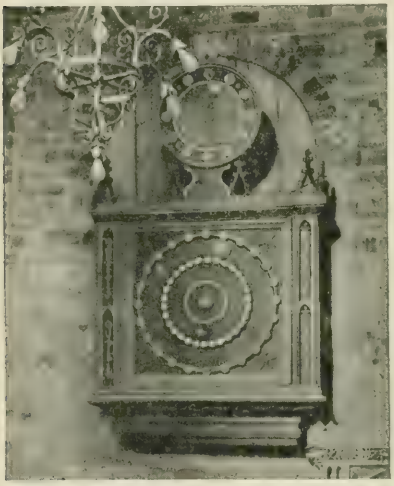


FIG. 37.—THE DIAL OF THE EXETER CATHEDRAL CLOCK.

On the North Wall of the North Transeptal tower, and near to the Chantry of William Sylke, is the dial, all that remains, in situ, of an ancient Horologe which has generally been regarded as the gift of Bishop Courtenay. There can be no doubt, however, that portions of the clock, which have been preserved in the Cathedral, are of much greater antiquity. The motion work is now driven or actuated by a new movement (1885), the going and quarters portion, combined, being in a chamber behind, and the hour striking over the vaulting or in the tower above, the disposal of parts being very much as in the old arrangement. All that remains, of various dates, of the ancient clock has been brought together, and is placed in the Sylke Chantry below, where visitors can see it in working order.

The dial is arranged on the Ptolemaic system of Astronomy which regarded the earth, represented by the central hemisphere, as the center of the solar system and the sun, represented by a fleur de lys, as revolving around it. The inner and outer figured circles are divided, the former from 1 to 30 (29½) days (in Arabic figures), representing the moon's age, and the latter, or outermost circle, into twenty-four hours, or two sets from I to XII, of which the uppermost XII represents mid-day and the lower mid-

night. The moon (half silver and half black), by its axial and orbital movements on the inner field, shows its varying phases (new, full, first, and last quarters, etc.) from day to day, while the aforesaid fleur de lys (the sun) points outwardly, on the Roman numerals, to the hour of day or night; and, by its central stem, inwardly to the moon's age on the inner circle of figures. Prior to the year 1760 (?) the main dial was only surmounted by cresting, but at this date the clock was entirely overhauled and the minute dial above added. The quarters 1, 2, 3, only were struck by the old, but the fourth has been added in the new clock on a small basin bell within the transept, just over the dial, and the hours are struck (as formerly, and by a separate movement), on the "Great Peter" bell in the tower above.

The motto upon the dial is:

PEREUNT ET IMPUTANTUR.

They (the hours) pass and are placed to our account.

One remarkable characteristic of the Exeter Clock, but little known, and in all probability nowhere else to be found, is the quaint arrangement for maintaining power during winding, a fact which places the device (of any form) centuries, it may be, before the date usually ascribed to its introduction.

The fine-toned bell, "Great Peter," is in the north tower. This bell was presented by Bishop Courtenay and recast by Thomas Perdue in 1676. Its weight is about seven tons and the diameter at the mouth about seventy-six inches.

The church of St. Mary of Ottery at Exeter also possesses a very old clock, dating from 1340, which was restored in 1906–7. The dial is now worked by what is supposed to be the old movement.

The Church of St. Mary Steps at Exeter also possesses a curious clock dating from the sixteenth century. It is located on the outside of the church, as shown in Fig. 38. The dial has but one hand and the corners are embellished with representations of the four seasons. Above the small dial is a large covered alcove containing three automatic figures or jacks. The central one is supposed to be a statue of Henry VIII, and as the clock strikes he inclines his head.

On each side is a soldier with a javelin in one hand and a hammer with a long handle in the other. These soldiers strike the quarters on two bells beneath their feet. These figures are popularly known as Matthew the Miller and his

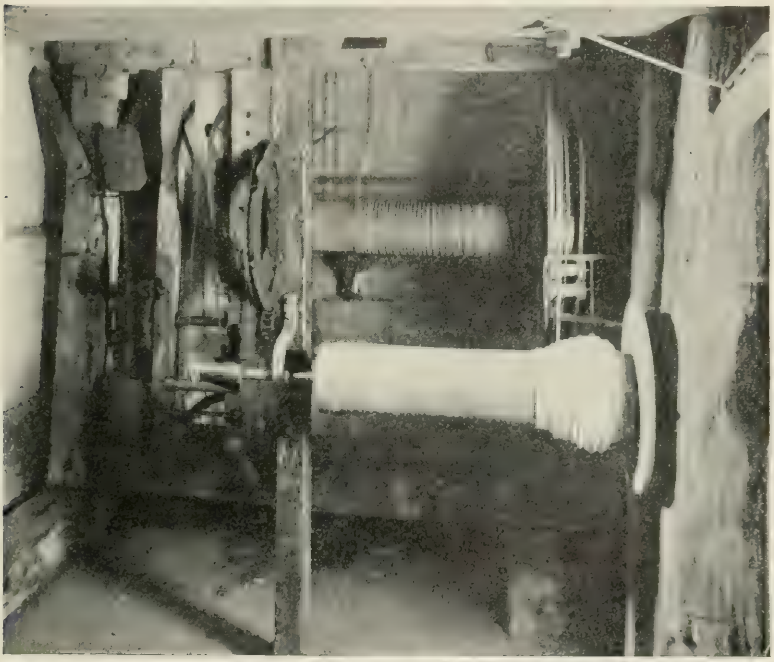
FIG. 38.—THE SIXTEENTH-CENTURY CLOCK ON THE CHURCH OF ST. MARY STEPS AT EXETER, ENGLAND.

two sons. He was, as the story goes, remarkable for his punctuality.

Peterborough Cathedral also possesses an old clock supposed to date from 1320. In 1836 it was completely renovated. The old movement is located in the tower and there is no dial. In Fig. 39 is shown a fine photograph of

it which was taken under great difficulties. The appearance of it attests its great age, but how often it has been repaired, renewed, and renovated it is impossible to state. The bell on which the hours are struck weighs 3200 pounds.

Wimborne Minster in Dorsetshire also possesses a fine old clock which dates from 1320. The dial reminds one



Courtesy, H. Plowman, Peterborough, England

FIG. 39. — THE OLD CLOCK MOVEMENT IN PETERBOROUGH CATHEDRAL.

very much of the clock in Exeter Cathedral and it is still worked by what is believed to be the original movement.

According to the records of Norwich Cathedral there must have been a clock there as early as 1323. It appears that this horologium was an elaborate piece of mechanism furnished with many painted images, which no doubt performed curious evolutions. There was a set of twenty-four small images, probably impersonating the hours of the day

and night. There were also thirty images, doubtless representing the days of the month. There were painted and gilded plates portraying sun and moon, and a procession of monks formed part of the mechanical pageantry. At present there is practically nothing to be seen. The small quarter jacks which were formerly in a recess of the south aisle and were moved by wires from the clock are now on "exhibition only" and the bells in the tower are actuated by a new movement there.

In 1326 Richard Wallingford, Abbot of Saint Albans, placed a clock in his monastery. His account of it still exists in the Bodleian Library at Oxford. There is no mention of any escapement or regulator of any kind. It was still going in the time of Henry VIII (1509–1547), when it was considered a miracle of art. It noted the course of the sun and moon, the rising and setting of the planets and the fixed stars, and the ebb and flow of the tides.

A very early clock, about which we have authentic details, was constructed in 1335 by Peter Lightfoot, an ingenious monk of Glastonbury Abbey, for and at the expense of his superior, Adam de Sodbury, who was promoted to the Abbacy of Glastonbury in 1322, and died in 1335. This complicated piece of machinery was originally in the south transept of the abbey church. It was afterwards removed with all its appendages to Wells Cathedral at the time of the dissolution of the monastery in the reign of Henry VIII. It still remains in an old chapel in the north transept. The dial is six and a half feet in diameter and is contained in a square frame.

It is an ingenious mechanism and indicates the hours of the day and night, the minutes, the age of the moon, and the moon phases. When the clock strikes the hour, horsemen, fully armed, dash out of two gateways in opposite directions. They strike with their lances as they pass as many times as correspond with the hour. A little distance away is seated a figure which kicks the quarters on two bells, placed beneath his feet, and strikes the hour on a larger bell with a battle-axe. Outside the transept is an-

other dial and two bells on which two armored knights strike the quarters. The works of the clock were of iron and wore out and were replaced in 1835 by Thwaites and Reid. The old works are now at South Kensington Museum. The costumes of the figures and the armor of the

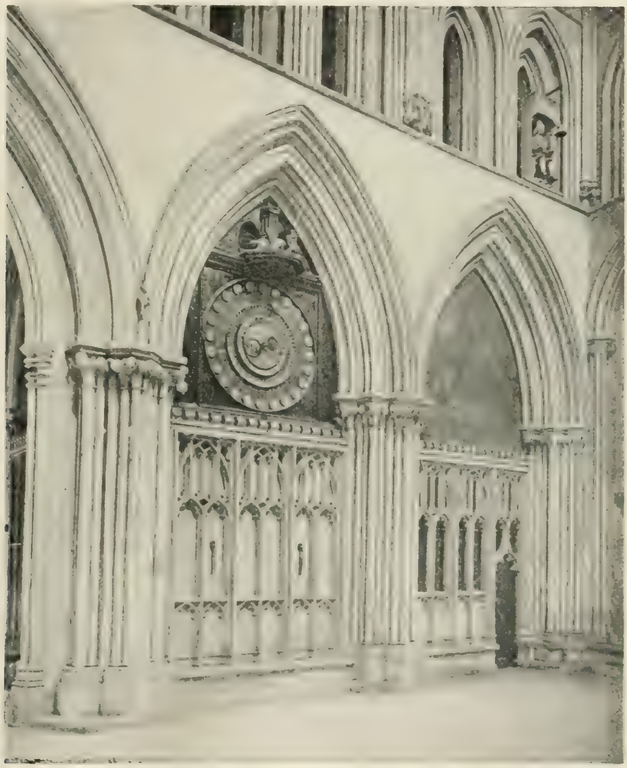


FIG. 40.—THE PRESENT APPEARANCE OF THE WELLS CATHEDRAL CLOCK.

jacks indicate a much later date. This simply means that from time to time the parts were reconstructed and somewhat changed. The original movement seems to have been almost identical with that of De Vick's clock. The present appearance of the clock is shown in Fig. 40.

In 1340 a clock was given to the Monastery of Cluny by Abbot Pierre de Chastelux. This clock not only indicated the phases of the moon, the movements of the sun, and the like but also had a quantity of figures which enacted scenes. The hours were announced by a cock, which fluttered its wings and crowed twice.

In 1344[1] by order of Hubert, Prince of Carrara, a clock was made by John Dondi at Padua. This seems to have been a true mechanical clock and attracted wide attention. It is described as being placed on the top of a turret on the steeple and designating the twenty-four hours of the day and night. So famous did its maker become that he was called "Dondi d'Orologia."

A turret clock was erected at Dover Castle in the fourteenth century. On the wrought iron frame are the letters R. L. and the date 1348. The mechanism seems to have been similar to that of De Vick's clock at Paris. This clock is now at the South Kensington Museum.

The first clock at Strasbourg was begun under John, Bishop of Lichtenberg, in 1352, and completed two years later. It was quite complicated, showed the motion of the heavenly bodies, and enacted certain scenes by means of automatons. Of its mechanism we know practically nothing. A few wheels may still be in existence. The second clock, constructed in 1570, was almost entirely new and very much more elaborate. The one at present in the cathedral is the third clock and was finished in 1842 by Jean Baptiste Schwilgué. These clocks will be considered in detail in a later chapter.

Clocks at Genoa in 1353 and at Bologna in 1356 are also mentioned.

In 1356–61 a famous clock was constructed for the Frauenkirche in Nürnberg. The maker is unfortunately unknown. It was a complicated piece of mechanism and is usually considered one of the earliest of the elaborate clocks. The Emperor, Charles IV, was represented, seated upon a throne; at the stroke of twelve, the seven Electors,

[1] The date is variously given as 1334, 1344, and 1350.

large moving figures, passed out and bowed before him to the sound of trumpets. This clock is located over the portal of the West Portico, and is known now as the "Männleinlaufen." It is stated by some that the clock was constructed in 1506–9 by G. Heuss and Seb. Lindenast. Its present appearance is shown in Fig. 41.

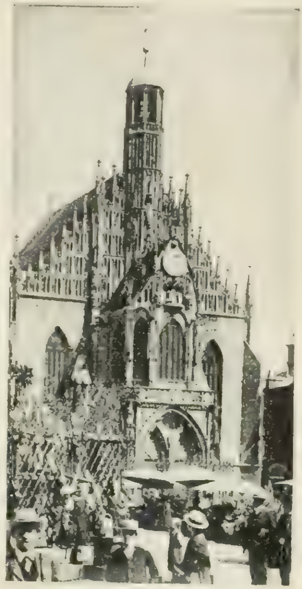


Photo. Underwood & Underwood, London.

FIG. 41. — THE FAMOUS CLOCK ON THE FRAUENKIRCHE IN NÜRNBERG.

There is a description only of a famous clock in the Palace of Abu Hammou, Sultan of Tlemcen, in Algeria. It was first seen in 1358. Each hour an elaborate scene was enacted.

Many references to the striking of clocks are to be found in the works of the old writers. Dante, who died in 1321, frequently mentions it. Chaucer, who died in 1400, speaking in one place of the crowing of a cock, says: "Full sikerer (surer) was his crowyng in his logge as is a clok, or any abbay orlogge."

CHAPTER V

THE CONSTRUCTION OF THE SIMPLEST POSSIBLE CLOCK

Introduction. — It might naturally be expected that this chapter would begin with a full description of De Vick's unquestioned mechanical clock of 1360. This has, however, been deferred until the next chapter, and the present chapter deals with the mechanism of the simplest possible clock. The reason for breaking this natural sequence is because this book will fall into the hands of many different classes of readers. Some will be clock repair men who know clock mechanism thoroughly. Others may have been attracted to clocks by the lure of the antique and may have never looked inside a clock. It seemed best therefore to take up clock mechanism in its simplest form here so that future descriptions might be more readily understood by all. The simplest clock will, of course, not be a striking clock; it will have no calender attachments or complications of any kind. It will be simply a timepiece in the primitive meaning of that term.

The four groups of parts. — Clock mechanism consists of four groups of parts: the *driving* mechanism, the *transmitting* mechanism, the *controlling* mechanism, and the *indicating* mechanism. The driving mechanism supplies the power and tries to drive the clock or cause it to run as fast as possible. The transmitting mechanism simply communicates the motion to the controlling mechanism. The controlling mechanism allows the clock to run just so fast and no faster. The indicating mechanism simply indicates how fast the clock is running.

The driving power may be either a weight or a coiled spring. Historically the weight was used a good four centuries before the spring. At present one is used as much as the other. We will consider here that the clock is weight-

driven. There are several ways of attaching the weight. There may be a pulley at the top of the weight around which passes a cord. One end is attached to the frame of the clock and the other is wound around a drum. This drum, or the axle to which it is rigidly fastened, is connected by means of a ratchet and click to a large cogged wheel which rides freely on the axle and supplies the power to the transmitting mechanism. The main driving wheel from a small clock with its ratchet and click is pictured in Fig. 42. This driving wheel must be connected with the drum through the ratchet and click and cannot be rigidly attached to it, in order that the weight may be wound up after it runs down. A ratchet and click in connection with the drum may be seen in Fig. 48. The weight is wound up by means of a key which has a square hole in it which fits over the squared end of the axis or arbor to which the drum is fastened. Another way is to attach the weight to the end of a flat chain which passes over a grooved wheel provided with points to keep the chain from slipping. This grooved wheel is again connected by means of a ratchet and click to the large cogged driving wheel. The weight is wound up by simply pulling the free end of the chain. In still another form the cord after leaving the drum passes over a pulley at the top of the clock case and then to the weight. These three ways of attaching the weight are shown diagrammatically in Fig. 43, on page 76.

FIG. 42. – A MAIN DRIVING WHEEL WITH ITS RATCHET AND CLICK.

The transmitting mechanism consists of a series of cogged wheels working one in another and is sometimes called the time train. The larger cogged or toothed wheels always do the driving. The smaller wheels which are driven are wider and have horizontal serrations or cogs which are called leaves. These driven wheels are called pinions. On

each axle or arbor there is rigidly fastened a wheel and a pinion. The ends of the arbor are called pivots and these run in holes in the frame or plates which hold the clock mechanism. These holes are jeweled in good watches and a few clocks. In Fig. 44 some arbors with wheels and pinions are shown. Arbors, with wheels and pinions, are also distinctly visible in Figs. 47, 48, and 152. The time train of a clock will contain at least one and may contain as many as five of these axles. It depends a little upon the maker, but chiefly on the length of time the clock is to run. There

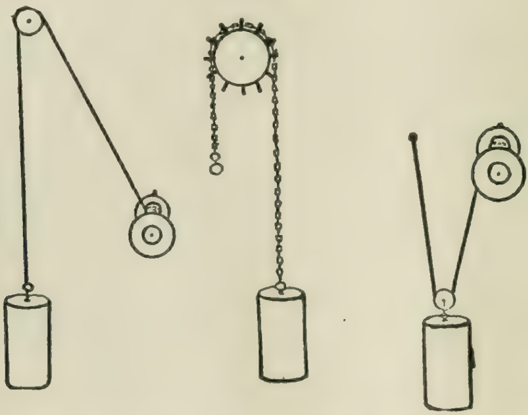


FIG. 43. — THE THREE WAYS OF ATTACHING A WEIGHT TO A CLOCK.

are one-day clocks, one-week clocks, one-month clocks, and one-year clocks. In each case the clock will actually run about twenty-five per cent longer than the specified time. That is, a one-day clock will run about thirty hours before it runs down. The great toothed wheel of the driving mechanism drives the pinion on the first axle. Its wheel drives the next pinion and so on until the wheel on the last axle drives the pinion on the axle of the escape wheel which is a part of the controlling mechanism. In this way the transmitting mechanism lives up to its name and simply transmits the motion from the driving to the controlling mechanism. Each axle turns faster than its predecessor

and with less power. If the above is not clear, look inside a clock. In fact this chapter can hardly be understood by one who has never seen the inside of a clock, if such there be.

The controlling mechanism is sometimes called the regulating mechanism. In De Vick's clock it consisted of a foliot balance, verge, and crown wheel (see page 83). This form has gone entirely out of use, however. There are probably between 200 and 300 different forms of controlling mechanism which have been devised and applied by some maker to a clock or watch. Less than ten have stood the test of time and become at all popular or common. Most of these will be described in later chapters. We will assume that this simplest possible clock has a pendulum, anchor escapement, and escape wheel. This is one of the commonest forms of controlling mechanism. The last wheel in the time train drives the pinion on the escape wheel arbor. The escape wheel itself has rather long pointed teeth inclined at an angle. Over a certain number of these teeth extends the anchor and to it is attached the pendulum. The action will be clear from Fig. 45. As the pendulum swings to the right a tooth at *A* escapes, but the escape wheel is not free to turn rapidly, as a tooth at *B* will strike the other horn of the anchor. As the pendulum swings to the left, the tooth at *B* escapes, but another tooth is caught at *A*, so that for each swing of the pendulum one tooth goes past first at *A*, then at *B*. It is this action of the escape wheel and anchor which causes the ticking of a clock. As a tooth escapes it gives a little push to the pendulum which keeps it swinging. It is therefore not the pendulum which makes a clock go,

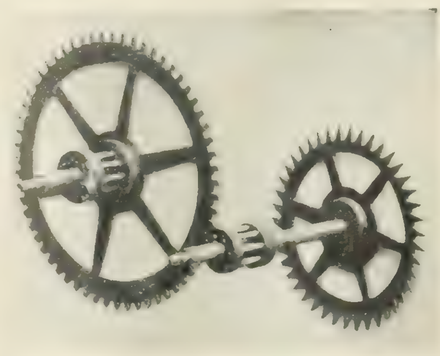


FIG. 44. — ARBORS WITH WHEELS AND PINIONS.

as some foolishly suppose, but it is the clock which keeps the pendulum going. Thus the rate of running is controlled,

FIG. 45. — AN ANCHOR ESCAPEMENT AND PENDULUM.

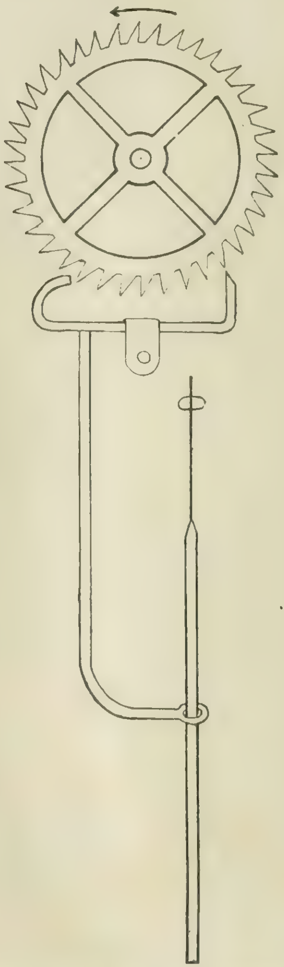


FIG. 46. — A SO-CALLED AMERICAN ANCHOR ESCAPEMENT, CRUTCH, AND PENDULUM.

for it must run at the rate of one tooth for the full time of swing of the pendulum. In Fig. 46 is shown another way

of attaching the pendulum and another form of anchor. The rod connecting anchor and pendulum is called the crutch, and the anchor is often spoken of as the verge. This can also be well seen in Fig. 151.

The indicating mechanism consists of the hands and dial and the "under-the-dial" mechanism, which is often called "motion work." A clock is always constructed so that some one axle in the time train turns in just one hour. This axle is in the center of the clock and is brought through almost to the dial. Over it fits, friction tight, a cap. This cap extends through the dial and carries the minute hand. To the other end of the cap is attached a cogged wheel, which drives a pinion, to which is attached a wheel, which drives a pinion attached to a second cap, which fits friction tight over the first cap and carries the hour hand. These two caps and four wheels are known as the under-the-dial mechanism, since that is their location. The wheels are of such size and number of teeth that one cap turns twelve times as fast as the other. This mechanism not only allows the hour hand to be moved by the minute hand but also permits a clock to be set. When a clock is set these friction-tight caps turn on each other and on the arbor.

FIG. 47.—THE MECHANISM OF A SIMPLE TIMEPIECE.

In Fig. 47 the mechanism of a fairly simple clock is shown complete. The four groups of parts can be easily distinguished.

In Fig. 48 is pictured a modern clock movement (No. 77B) made by the Seth Thomas Clock Co. at Thomaston, Conn. The motion work is well visible and also the four groups of parts.

Having now mastered the fundamental principles of clock mechanism we are ready for a description of De Vick's clock.

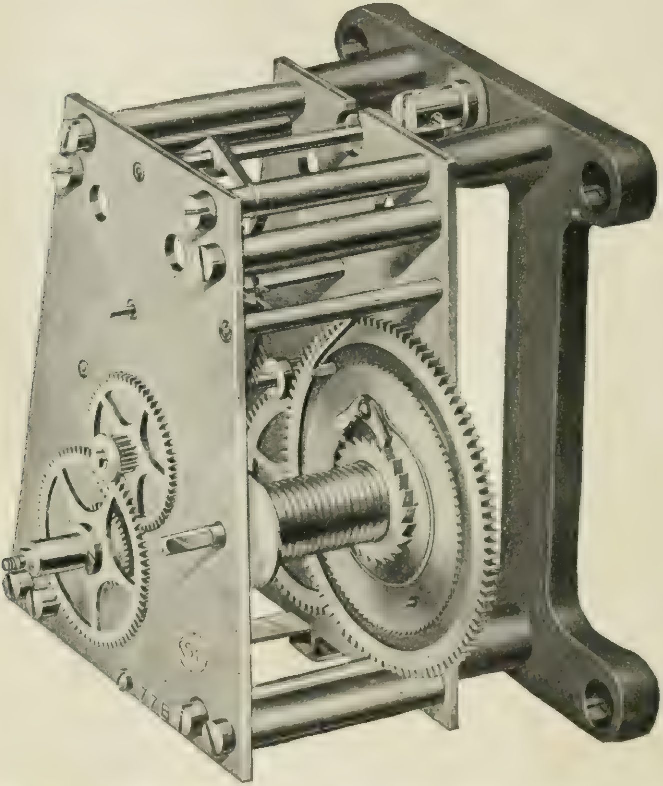


FIG. 48. — A MODERN CLOCK MOVEMENT, BY THE SETH THOMAS CLOCK CO., SHOWING "MOTION WORK."

CHAPTER VI

THE HISTORY OF CLOCKS FROM 1360 TO 1500

A description of De Vick's clock. — The year 1360 is chosen for the beginning of this period because then, or according to some writers a few years later, Henry Wieck, or, as he was later called, Henry De Vick (Henri de Vic), of Würtemberg, constructed a clock for Charles V of France. It was placed on the Royal Palace, which is now the Palais de Justice in Paris. Its present appearance is illustrated in Fig. 49. De Vick was lodged in the tower while working on the clock and was paid at the rate of "six sous Parisis" a day. It required eight years to complete the work. The present architectural surroundings of the clock date from 1585 and the clock itself has been repaired and renovated several times, the last time in 1852. The dial is shown in Fig. 50. It had but one hand, and the spaces between the hours were each divided into five equal parts. The figures of Piety and Justice which flank the dial are by Germain Pilon and the bell on which the hours are now struck was cast by John Jouvance. This is the first unquestioned mechanical clock about which we have fairly complete information. A description of it has come down to us from the famous Julien Le Roy (born 1686, died 1759), who examined it while it was still in running order, and in its original condition. It was a comparatively simple clock, for it kept time and struck the hours and did nothing else. There were no additions or complications of any kind. There were also no automatic figures to enact scenes at the various hours or particularly at the hour of twelve, as was the case with so many of the ponderous, complicated clocks of the time. The clock mechanism was in two distinct parts, connected by only one rod. The weight which drove the time-

FIG. 49. — DE VICK'S CLOCK ON THE PALAIS DE JUSTICE, IN PARIS.

keeping part weighed 500 pounds and the striking weight weighed 1500 pounds.

Front and side views of the timekeeping half of the mechanism are shown in Fig. 51. The heavy weight *A* was attached directly to the rope, which was wound around the drum *B*. This drum was loose upon its arbor and was connected by means of a ratchet and click seen at *F* to the main driving wheel *G*. In order to make the winding of the heavy weight easier there was a separate winding arbor *P* which carried a cogged wheel, *n*, which drove another larger cogged wheel, *Q*, which was firmly fastened to the drum. With this arrangement the winding would take much longer, but far less strength would be required. The winding handle was placed on the squared arbor of *P*. These parts just described constituted the *driving* mechanism. The time train or *transmitting* mechanism consisted of just one wheel and pinion. It is shown at *H* in the figure.

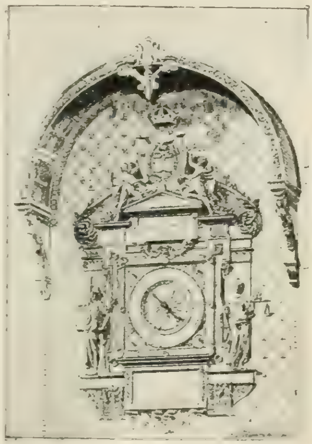


FIG. 50. — THE DIAL OF DE VICK'S CLOCK.

The *controlling* mechanism consisted of a crown wheel, *I*, verge escapement, *K*, and foliot balance, *L*. These parts are shown in detail in Fig. 52. The crown wheel looks something like a crown and is serrated with teeth like those of a saw, placed parallel with its axis. The verge (from a Latin word meaning to turn round) escapement consists of a rod pivoted at its foot, suspended by a string to take most of the weight off the support, and provided with two blades or pallets nearly at right angles to each other which engage the teeth of the crown wheel. The foliot balance swings in a horizontal plane and is rigidly fastened to the verge. It is provided with two weights which can be moved in or out and thus determine the time of swing of the balance. The

action of this controlling mechanism is apparent from its construction. The last wheel in the time train drives the pinion on the crown wheel axle and thus constantly tries to turn the crown wheel. As the foliot balance swings in one direction and turns the verge, a tooth of the crown wheel escapes at one pallet. But the crown wheel cannot turn far, as a tooth on the opposite side is caught by the other pallet. The foliot balance eventually comes to rest and

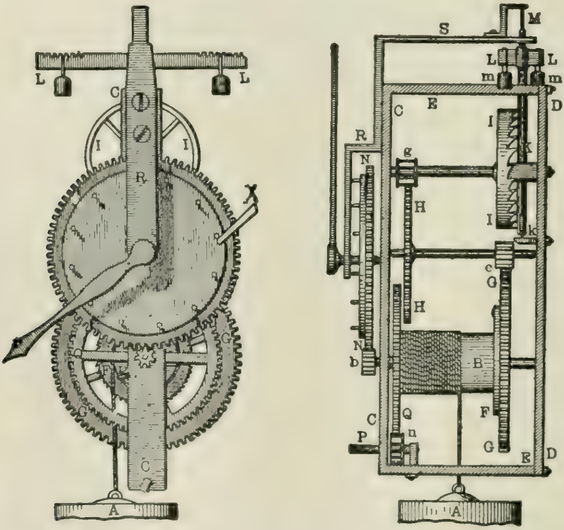


FIG. 51. — A FRONT AND SIDE VIEW OF THE TIMEKEEPING MECHANISM OF DE VICK'S CLOCK.

starts to swing in the opposite direction. This finally releases the tooth of the crown wheel and allows it to again advance until a tooth on the opposite side is caught. As these teeth escape a push is given to the pallets which keeps the balance swinging.

The *indicating* mechanism was extremely simple. As there was but one hand no under-the-dial mechanism was necessary. On the arbor of the main driving wheel at *b* was placed a small cogged wheel which drove a larger cogged wheel, *N*, to whose arbor was attached the hand

which moved over the dial. Under this hand there is seen a plate with twelve pins. This really belongs to the striking mechanism. Each hour one of these pins pressed down and finally released the rod, *X*, which started the striking mechanism which constituted the other half of the clock.

It will now be seen that this clock of De Vick's was a self-contained, weight-driven, mechanically-controlled clock

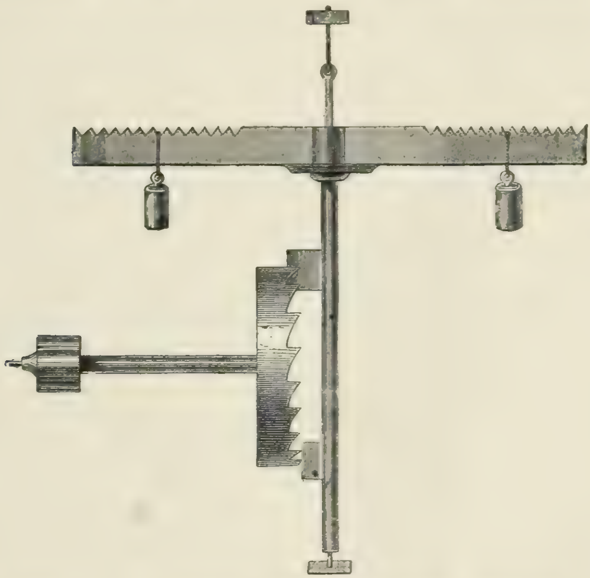


FIG. 52. — THE CONTROLLING MECHANISM OF DE VICK'S CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

and thus worthy to be considered a clock in the modern sense of the term. As far as its time-keeping qualities are concerned, it is said that it did not keep time much nearer than *two hours a day*. Think of it! In the fourteenth century the accuracy of the best timekeeper was two hours a day! And at that it probably did better than a clepsydra, for it was Seneca, I believe, who, speaking of Roman timekeepers, remarked that philosophers agree more readily among themselves than clocks.

Tower clocks and cathedral clocks. — During this period from 1360 to 1500 tower or turret clocks and immense ponderous clocks to be placed inside cathedrals and public buildings continued to be constructed in ever increasing numbers and complexity. There were no improvements or changes in the mechanism. They were all constructed, with the exception of very minor modifications, exactly like De Vick's clock of 1360. The tower clocks were as a rule the simpler. They very often simply kept time and struck the hours. The clocks placed inside the cathedrals were often fifteen, twenty, even thirty, or forty feet high, with other dimensions to correspond. They were usually extremely complicated. Sidereal and true solar time were often indicated as well as mean solar time (standard time had not yet come into existence). The motions of the sun, moon, and planets were shown. A perpetual calendar, including the various church festivals, was indicated. Marionette exhibitions took place each hour and sometimes at the hour of twelve elaborate scenes were enacted by means of automatic figures or puppets.

It is of course impossible to state exactly how many clocks had been constructed before 1500, but by this date nearly every large city of note had at least one tower clock and nearly every noteworthy cathedral had its elaborate clock. In the year 1500 the crest of the wave of enthusiasm for the building of this type of clock had not yet been reached. This came a century or so later. A few of these elaborate clocks will be described in detail in a subsequent chapter.

Domestic clocks. — It is a very interesting question as to whether the domestic or chamber clock made its appearance before 1500. By a domestic or chamber clock is meant a little clock which an ordinary well-to-do householder could place in an ordinary room of his house. Were they made small enough and cheap enough for this purpose? The evidence is of three kinds. There are in the museums a very few, questionable, rebuilt, domestic clocks supposed to date from before 1500. There are two or three representations of such clocks and lastly there are quite a few

references to little portable clocks in old letters and manuscripts. A portion of a letter written by Sir John Paston in 1469 is as follows:

> I praye you speke wt Harcourt off the Abbeye ffor a lytell clokke whyche I sent him by James Gressham to amend and yt ye woll get it off him an it be redy, and send it me, and as ffor mony for his labour, he hath another clok of myn whiche St. Thoms Lyndes, God have hys soule, gave me. He maye kepe that tyll I paye him. The klok is my Lordys Archebysshopis but late him not wote off it.

Perhaps the very first reference to domestic clocks is contained in a poem, entitled the "Romaunt de la Rose" and written by Jean de Meum about 1305. It is in French and the four lines in question have been translated thus:

> And then he made his clocks strike
> in his halls and in his chambers,
> with wheels very subtily contrived
> with a continuing movement.

It would thus seem that the domestic clock did make its appearance before 1500, but it is equally certain that they were very few in number and not at all common. In form they were probably like the "bird cage" or "lantern" clocks which became very common in the century following 1500. The mechanism was probably identical with that of De Vick's clock, only on a much smaller scale.

The year 1500 is chosen as the year for ending this period not because it is the end of a century but because in that year a great invention was made by Peter Henlein or Hele of Nürnberg. The mainspring, as a source of power for driving clock mechanism, was discovered. From this point on our history divides into two parts. We must consider the weight-driven clock on the one hand and the spring-driven clock, clock-watch, and eventually watch, on the other. Up to this time, 1500, there were but three kinds of mechanical timekeepers in existence, namely, tower clocks, ponderous cathedral clocks, and a very, very, few domestic or chamber clocks.

CHAPTER VII

THE HISTORY OF WEIGHT-DRIVEN CLOCKS FROM 1500 TO 1658

The title of this chapter is the history of clocks from 1500 to 1658. It might have been called the history of clocks from the invention of the mainspring to the invention of the pendulum, for it is these two inventions which set the bounds for the period. In this chapter only weight-driven clocks will be considered. Spring-driven timekeepers of this same period will be taken up in subsequent chapters.

Tower clocks. — During this period tower or turret clocks continued to be built in large numbers. Cathedrals, churches, monasteries, castles, and public buildings were almost always supplied with them. The tower clocks tended if anything to become more simple. Usually they did nothing but indicate the time on a dial and strike the hours, although at times there were chimes at the quarters and before the strokes of the hour. There still continued to be but one hand, namely, the hour hand. In a very few cases just before the close of the period the minute hand had perhaps been added. No improvements were made in the mechanism except greater care in the construction. They were weight-driven and controlled still by the foliot balance, verge, and crown wheel, just as in De Vick's clock nearly three centuries before. There seems to have been a remarkable lack of interest in the timekeeping accuracy of clocks. Great pains were taken with the decoration of the dial or the outward appearance of the timekeeper, but there seems also to have been an almost unexplainable apathy as to the timekeeping qualities of the clock. Perhaps a half hour was not as precious then as now.

Cathedral clocks. — Large, ponderous clocks for the interior or exterior of cathedrals and public buildings also

continued to be constructed. They were always extremely elaborate, indicating various kinds of time, calendar changes, and the positions of the heavenly bodies. Scenes were enacted by means of puppets. Not only were the hours struck on a bell, but cocks crew, lions roared, drums were beaten, and the like. The mathematician, the astronomer, and the mechanician joined forces to make these clocks as intricate as possible. The middle of the period just about marks the crest of the wave of enthusiasm for this type of clock. By the end of the period there was very much less interest. Two things probably brought this about. In the first place there were more kinds of clocks to claim the interest and, secondly, the coming of the domestic or chamber clock dissolved the mystery which had for centuries hung about clock mechanism.

A few "cathedral clocks on a diminutive scale," if we may coin a descriptive phrase for them, were constructed during this period. They were from four to six feet high and very intricate. It was an attempt to construct on a small scale a clock which would perform as many as possible of the operations of the ponderous cathedral clocks. There are but very, very few of them. All the museums and collections of the world probably contain less than twenty-five. One or two of them will be described in a later chapter (XXV) on "Some Famous Clocks and Watches."

Domestic clocks. — The all-important event during this period was the coming of the domestic clock. By a domestic or chamber clock is meant one which, in contrast to the tower or cathedral clock, was so small and cheap that the well-to-do householder could afford to own one and could place it in any ordinary room. These domestic clocks probably originated before 1500; it was nearly 1600 before they were at all common; by the end of the period, 1658, they were to be found, particularly in England, almost everywhere. They were all practically identical in appearance and construction. They are spoken of as the "bird-cage," "lantern," "bed post," or "Cromwellian" clock and a few are illustrated in Figs. 53 to 58. "Lantern"

clock is probably the more usual name now. It was so called because it followed the form of the lantern of the period and, like it, was hung on a wall. Some were so small as to have a dial not more than 3 inches in diameter. The larger ones would have a dial perhaps 10 or 12 inches in diameter. If there was any pronounced tendency it was perhaps to become a little larger towards the end of this period. They were usually striking or alarm clocks. The bell was placed at the top and the striking mechanism was always separate and placed behind the time mechanism. They were usually constructed to run 30 hours, never any longer. This required a long fall for the weight. Sometimes they ran only 12 hours.

Around the top there were brass ornaments called "frets," usually three in number, one in front, and one on each side. In the beginning each maker probably had his own style of fret, but they were much copied, so that the fret now indicates the date of a clock rather than its maker. Sometimes a space was left for the name of the maker or owner. Some of the frets are heraldic in nature. The crossed dolphin fret is a very common one. This came in about 1640 or perhaps a little earlier. It is sometimes said to have been the coat of arms and later the trade mark of Thomas Tompion, a very famous clockmaker of London, who was born in 1639 and died in 1713. This is hardly possible, however, as this form of fret was in use even before Tompion's birth. The statement is made by one writer that the heraldic fret was used from 1600 to 1640; the dolphin fret from 1650 on; and various other frets from 1680 on.

The brass sides of the clock were often etched and chased and sometimes mottoes were engraved on them. Perhaps they were decorated in accordance with the taste of the would-be purchaser. The dials were of brass, often thickly gilt, and sometimes with a silvered strip for the hour numerals. There was but one hand, the hour hand. The spaces between the hours were sometimes not divided at all, but usually they were divided into fourths or fifths.

FIG. 53. — A BRASS LANTERN CLOCK, BY WILLIAM PAYNE, 1618, AND NOW IN THE COLLECTION OF PERCY WEBSTER.

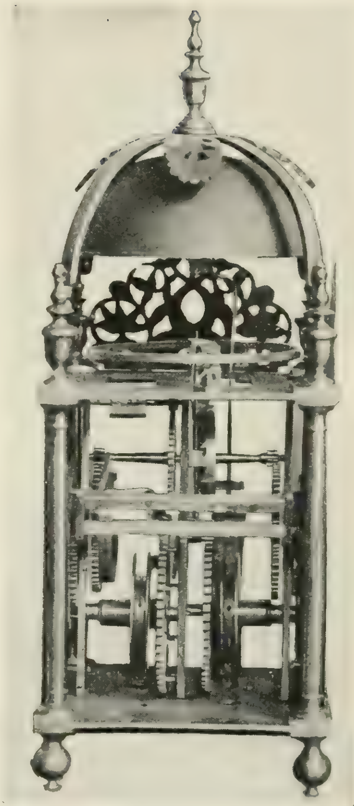


FIG. 54. — THE MOVEMENT OF A LANTERN CLOCK.

FIG. 55. — THE FOLIOT BALANCE OF A LANTERN CLOCK.

The dials were often a little larger than the front of the clock.

These clocks were true bracket clocks in the sense that it was necessary to place them on a bracket in order to have a long free fall for the weights. These brackets, particularly in the Netherlands, were often elaborately carved and decorated. Sometimes, however, the clocks were simply spiked or fastened to the wall.

The mechanism of these clocks was extremely simple. The heavy weights were fastened to the ends of flat chains or in the earlier clocks to plaited ropes which passed over grooved wheels with points to keep the ropes from slipping. They were wound up by pulling the free ends of the ropes. There were four corner posts connecting the top and bottom plates. The pivots ran in vertical pillars running between the plates. The time train consisted of one wheel and pinion. The controlling mechanism was the usual foliot balance, verge, and crown wheel. This was exactly like De Vick's clock, except that the foliot balance instead of being a single rod with weights had been developed into a full wheel. It was at the top of the clock under the bell just above the top plate. There was no under-the-dial mechanism and just one hand. The striking mechanism always occupied the back half of the clock.

Fig. 53 illustrates such a lantern clock made by William Payne in East Smithfield, England, in 1618, and now in the private collection of Percy Webster. It is a striking clock 15¼ inches high over all, 6¼ inches wide and 5¾ inches deep. It has a one-inch hour circle. Fig. 54 shows the mechanism of the clock. One side and the fret above have been removed. The foliot balance wheel at the top can be plainly seen, and is illustrated separately in Fig. 55. The weight ropes have been removed, but the grooved wheels with the points can be easily recognized. The right-hand half of the mechanism is for timekeeping and the left-hand half makes up the striking mechanism.

Fig. 56 illustrates a fine seventeenth-century lantern clock which is now in the British Museum in London. It

FIG. 56.—A SEVENTEENTH-CENTURY BRASS LANTERN CLOCK, NOW IN THE BRITISH MUSEUM.

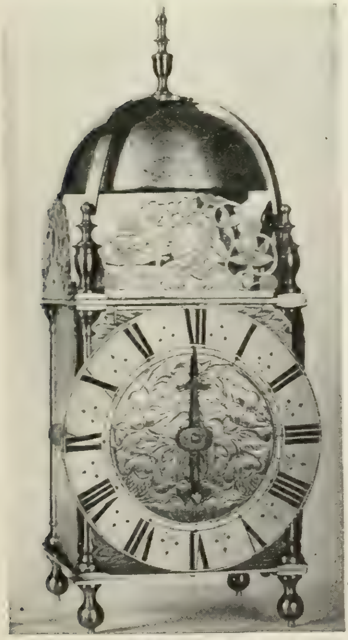


FIG. 57.—A LANTERN CLOCK, BY THOMAS TOMPION, NOW IN THE BRITISH MUSEUM.

FIG. 58.—A BRASS LANTERN CLOCK, BY ANDREW PRIME, NOW IN THE SOUTH KENSINGTON MUSEUM

is in a fine state of preservation and the photograph is especially good. Unfortunately there is no name on it. The fret is a particularly fine example of the crossed dolphin fret and shows in general the careful work which went into fret construction. There is but one hand and the hour spaces are divided into four parts.

Fig. 57 illustrates a lantern clock, also in the British Museum, which was made by the famous Thomas Tompion, whose name can just be made out on the dial. It is an alarm clock and the inner circle of figures on the dial is for the alarm.

Fig. 58 illustrates a lantern clock which is now in the South Kensington Museum. It was an alarm clock, as is indicated by the inner circle of numbers on the dial. This clock now has a pendulum, which shows that it was rebuilt after 1658. The fret is identical with the one pictured in Fig. 56. This does not necessarily mean that it was by the same maker. On the dial may be read: "Andrew Prime Londini fecit." Andrew Prime was made a member of the Clockmakers' Company in 1647. Other clocks by him are also in existence. All four of the lantern clocks illustrated in Figs. 53–58 have but one hand and the form in each case is worthy of careful notice.

The Clockmakers' Guild. — This period also saw the rise of powerful trade guilds which had a profound influence on the making of clocks and watches. In 1630 a committee of London clockmakers was formed, money raised, and a petition for a charter sent to the king, Charles I. It was granted on August 22, 1631, and, as it was officially designated, "The Master, Wardens, and Fellowship of the Arts and Mystery of Clockmaking of the City of London" came into existence. This trade guild is usually spoken of as the "Clockmakers' Company," and in many books, after being once mentioned and explained it is referred to simply as the "C. C." David Ramsay was first master; Henry Archer, John Willowe, and Sampson Shelton were the first wardens; and James Vantrollier, John Smith, Francis Foreman, John Harris, Richard Morgan, Samuel

Linnaker, John Charlton, John Midnall, Simon Bartram, and Edward East were the assistants or as we would now call them, the committee of management. The offices were usually held in rotation, the master holding office only one year and then returning to the rank of assistant. The assistants were elected for life. There were quarterly dues and many rules and regulations for governing the trade and the conduct of the members. The company was empowered to make laws governing all persons in the trade in London itself, within ten miles of the city, and to a certain extent throughout the whole realm. Only one apprentice could be taken except by a master, warden or assistant, in which case there could be two. The length of service of an apprentice was five years and there were fairly heavy fines for disobeying the regulations. The company possessed the right of search ostensibly to prevent the "making, buying, selling, transporting, and importing any bad, deceitful, or insufficient clocks, watches, larums, sun-dials, boxes, or cases for the said trade." They could "enter with a constable or other officer any ships, vessels, warehouses, shops, or other places where they should suspect such bad and deceitful work to be made or kept for the purpose of searching for them." This right was actually exercised for more than a century. This Clockmakers' Company has continued to the present time. Now its magnificent horological library is in the Guildhall, as is also the fine collection of timekeepers. The records of the Clockmakers' Company are very complete, so that they are a reliable mine of information for determining the dates, place of business, and the like, of any old clockmaker.

The Paris Guild of Clockmakers was given its first statute of incorporation by Francis I in 1544. The signers of the petition were Fleurent Valleran, Jean de Presles, Jean Pantin, Michel Potier, Anthoine Beauvais, Nicholas Moret, and Nicolas le Contandois. The statute was changed several times during the next century. They, too, had elaborate rules and regulations for governing the trade, the taking of apprentices, and the like. It may have

been a proposal in 1627 to grant letters patent authorizing French clockmakers to carry on their trade in London which stirred up the London clockmakers to form their own trade guild.

The period treated in this chapter ends in 1658 with the introduction of the pendulum, an invention destined to practically revolutionize clockmaking.

CHAPTER VIII

THE WATCH OF TO-DAY

This is again an interpolated chapter. The natural expectation would be that the history of weight-driven clocks which was brought down to 1658 in the last chapter would be continued, or that the history of spring-driven timekeepers from 1500 on would be taken up. This has, however, been deferred until later chapters and the present chapter takes up in detail the construction of the watch of to-day. This may seem irrelevant here, but it is hoped that the insertion of this material will make the descriptions in later chapters much more interesting and easily understood.

At first thought it might be supposed that it would be necessary to consider some special model of one particular maker but that, fortunately, is not the case. All watches at the present time, particularly all American-made watches, are so nearly alike that a description of any one will give a good idea of the construction of all. The number of different sizes, models, and grades may mount up into the hundreds, but yet they are all very much alike in construction.

A watch consists of two parts: the case and the works or movement. It is often the case which first attracts attention, and many a watch is sold simply through its appearance, although the unseen movement is the all-essential part. In this chapter the movement alone will be considered.

Watch sizes. — The largest gentleman's watch now made is called 18-size. The 16-size is the one usually chosen; it is a little smaller. The 12-size, which is smaller still, is preferred by some who like a smaller, thinner, daintier watch. All watches used by railroad men must be either 18-size or 16-size. It used to be thought that a larger watch was

sturdier, could be more accurately adjusted, would keep better time, and stand more abuse. With the precision of modern construction a 12-size watch is probably now just as good for nearly all purposes as an 18-size.

These numbers, which express the size, are not arbitrary but are the number of thirtieths of an inch by which the diameter of the movement exceeds $1\frac{5}{30}$ inches. Thus the diameter of a 12-size movement is $1\frac{17}{30}$ inches and of an

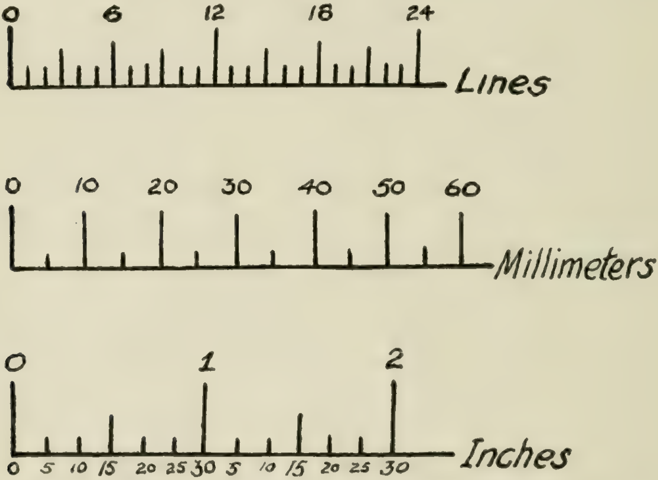


FIG. 59. — THE THREE SCALES FOR EXPRESSING THE SIZE OF A WATCH MOVEMENT.

18-size, $1\frac{23}{30}$ inches. It must be remembered that this is the diameter of the movement, not the case.

Not many years ago watch movements were perhaps not quite true to size, but that is not so at present. It is usually not the same firm which makes both case and movement, and thus it is absolutely essential that both be made true to size. One may choose a watch case at a jeweler's and have a great variety of movements placed in it. Some manufacturers, however, always case the movement at the factory and sell only complete watches. The claim is made that it is better to make the final adjustments to a watch

movement in its own case It also obviates the difficulty of having possibly an unskilled jeweler fit the movement to the case.

Ladies' watches are usually 0 size. That means the movement has a diameter of $1\frac{5}{30}$ inches. Some are smaller and the sizes run 00,000 even down to 000 000 0000. These are often written 2–0, 3–0, etc., to 10–0, or 2/0, 3/0, etc. The 00 movement has a diameter of $1\frac{4}{30}$ inch, the 000 a diameter of $1\frac{3}{30}$ inch and so on.

The size of the movement of a foreign watch is sometimes expressed in millimeters. It is only necessary to remember that 25.4 millimeters equal one inch.

Occasionally the size of a movement is expressed in "lines" or "lignes." It is only necessary to remember that a line is 2.26 millimeters. Thus a movement having a size of 8 lines would be about 18 millimeters in diameter. This would be a little more than $\frac{21}{30}$ inches, so that the size would be 15–0; a very small watch indeed, but there are watches made this small and even smaller.

In Fig. 59, on page 98, the three scales are shown together in natural size.

In Fig. 60 (a to f) are shown six watches of different sizes, one of 18-size, two of 16-size, one of 12-size, one of 0-size, and one of 5–0-size. They are all made by well-known representative American firms, as may be seen on the watches themselves, and are models which are manufactured at present. The illustrations are actual size.

Watch plates. — The wheels, pinions, and various parts which make up a watch movement are mounted between or attached to two plates which are the framework of the movement. These plates are separated by a small distance and held rigidly together by means of so-called "pillars." One plate is always a complete, round plate, but cannot be seen unless a watch movement is taken apart. It is directly behind the dial, so that it cannot be seen from the front and it cannot be seen from the back (at least a large part of it) because the other plate or the parts of the movement cover it. The second plate may also be a full plate. It

FIG. 60a.

FIG. 60b.

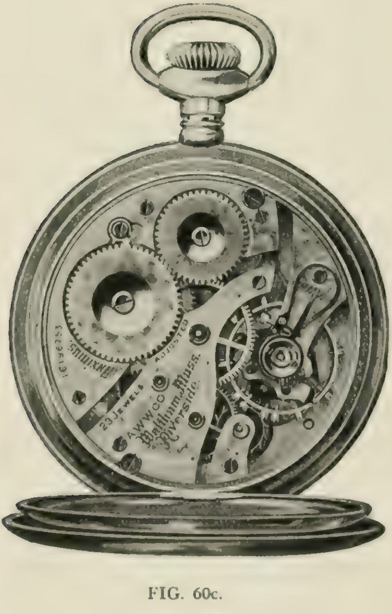


FIG. 60c.

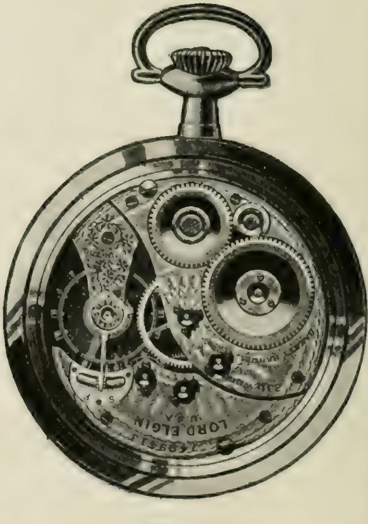


FIG 60d

may be partially cut away, in which case it is called a three-quarter plate movement. It may be replaced by a series of bars or bridges which extend over the works and hold different parts. In this case the movement is called a bridge model. In Europe such a movement is usually called a Geneva bar movement. There are thus full-plate, three-quarter-plate, and bridge model movements and these three kinds are illustrated in the three watches pictured in

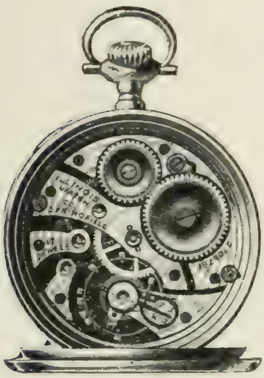


FIG. 60e.

FIG. 60f.

Fig. 61. They are American-made watches and are manufactured at present.

These plates are often of brass (an alloy of copper and zinc), usually heavily gilt. They may consist of a nickel alloy, i.e., nickel alloyed with zinc and copper. When finished with wavy lines, bars, or figures they are said to be "damaskeened." This ornamentation should perhaps be called snailing rather than damaskeening.

There is no decided modern tendency and yet on the whole there seems to be an increase of bridge models and a falling off in full-plate movements. The older, larger watches nearly always have a full plate. The smaller and newer ones are of the bridge model. Both have advantages. The full plate makes the watch a little more rigid and probably keeps more dust and lint out of the movement.

FIG. 61. — THREE WATCHES ILLUSTRATING THE THREE MODELS.

The bridge model is thinner, the balance wheel is less liable to be crushed in case of accident, and certain parts can be removed without taking down the whole movement. Of course a far better view of the watch movement can be gained, but that is hardly an advantage, for the less often a watch case is opened and the movement exposed to view, the better.

The four groups of parts. — Just as in the case of a clock, so also a watch movement may be considered to consist of four groups of parts. There is the driving mechanism, the transmitting mechanism, the controlling mechanism, and the indicating mechanism. The driving mechanism consists of the mainspring coiled in its barrel. The transmitting mechanism consists of three cogged wheels with pinions mounted on three axles or arbors. The controlling mechanism consists of balance wheel, balance spring, detached lever, and escape wheel. The indicating mechanism consists of the hands and dial and the under-the-dial mechanism or motion work. These parts will now be taken up in order and considered in detail.

The driving mechanism. — The power is supplied by the mainspring, which is a coiled ribbon of steel from about 24 to 10 inches long, depending upon the size of the watch and with a width and thickness to correspond. It is contained in a circular box called the barrel. One end of the spring is fastened to the inside of the barrel and the other to the arbor or axle upon which the barrel rides freely. Every American watch has a so-called "going barrel." This means that when the watch is wound, the arbor is turned, thus coiling the spring tightly around it. As the spring uncoils it pulls the barrel around. The edge of the barrel or a wheel attached to it is provided with teeth which mesh in the leaves of the pinion on the first arbor of the transmitting mechanism. This then becomes the driving wheel of the watch and supplies the power to the transmitting mechanism. A mainspring causes a barrel to rotate three times in 24 hours and five times before it completely uncoils and the watch runs down. Modern watches

are thus made to run 40 hours. In Fig. 62 are shown an empty mainspring barrel and the largest and smallest main-springs coiled in their respective barrels. Fig. 63 is a cross-section of a barrel, showing the barrel itself, its cover, the arbor upon which it rides, the hub, *C*, to which the main-spring is attached, and the jewels, *A*, *E*, in which the arbor runs.

FIG. 62. — EMPTY MAINSPRING BARREL AND LARGEST AND SMALLEST MAIN-SPRINGS.

A watch is either a stem-winder or is wound by means of a watch key. The modern watches are all stem-winders. Watches wound by means of a key are, however, simpler in construction. Here the arbor to which the mainspring is attached is prolonged until its squared end is visible in the hole in the inner case of the watch. When a watch is wound there must be a "ratchet and click" to prevent the mainspring from immediately uncoiling again. This consists of a toothed wheel called the ratchet which is firmly attached to the arbor. There is also a dog or pawl, called in watch work a click, which is fastened to one plate of the watch and is held against the ratchet by means of a click spring. The familiar clicking sound heard when a watch is wound is caused by the sliding of this click or pawl over the teeth of the ratchet. If a watch is a stem-winder, then two steel winding wheels are introduced between the barrel arbor and the wheels and parts attached to the stem. One of these wheels is fastened firmly to (that is it is squared onto) the barrel arbor. In this case no separate ratchet is necessary and the click is applied directly to one of the winding wheels. Sometimes a so-called recoiling

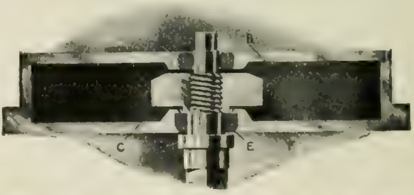


FIG. 63. — A CROSS-SECTION OF A MAIN-SPRING BARREL.
(Illinois Watch Co.)

click is used. That is, the mainspring is allowed to uncoil just a little before the click finally catches and holds. Such a one is pictured in Fig. 64, which shows well the winding wheels and the recoiling click. The advantage is that the mainspring is thus never left strained to the utmost by winding to the very limit. There are three disadvantages in leaving a mainspring wound up very tight. If the watch is at once exposed to a lower temperature the mainspring may break, due to contraction. The oil is squeezed

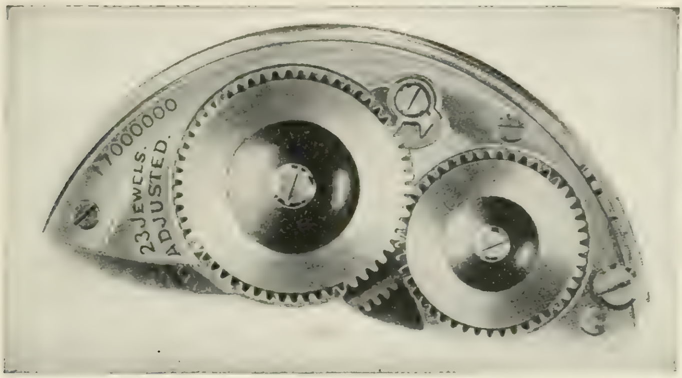


FIG. 64. — A RECOILING CLICK.
(Waltham Watch Co.)

out of the spring. Too much tension is put on the other parts of the watch movement, especially the lever and the pivots.

At the present time there are two attachments which are sometimes added to the driving mechanism. These are a winding stop, usually called a Geneva stop to prevent overwinding and an up-and-down winding indicator to show when the watch was last wound. Historically there are three other things which have been associated with the driving mechanism but are not to be found now on any American watch or, in one or two cases only, on any watch made at the present time. These are the "stackfreed," the "fusee" and "maintaining power." These five attachments will be fully considered later.

The transmitting mechanism consists of three axles or arbors each carrying a pinion and a wheel. The wheels are called the center wheel, the third wheel, and the fourth wheel. The reason for numbering in this way is because the teeth on the edge of the going barrel which mesh into and drive the pinion on the center wheel arbor are considered as constituting the first wheel. These are shown in Fig. 65, which is really a model of the essential parts of a watch. In the watches illustrated in Figs. 60 and 61 most of these parts can be made out. The wheels are either brass or gold and the pinions and arbors are made of steel. Fig. 66 pictures a typical center wheel and also a wheel and pinion fastened to an arbor.

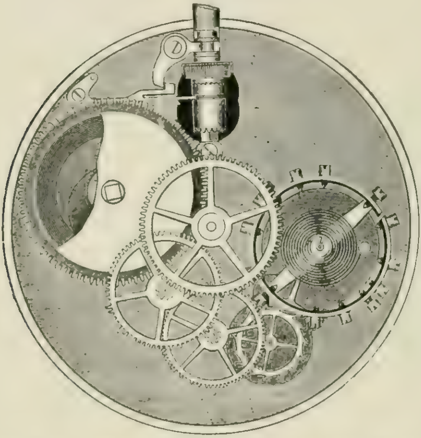


FIG. 65. — A MODEL OF THE ESSENTIAL PARTS OF A WATCH.
(Waltham Watch Co.)

The going barrel turns once in eight hours. The ratio between the number of teeth on the barrel and on the center pinion is always 8 to 1, so that the center arbor turns in just one hour. This arbor is placed in the center of the watch and is prolonged through the dial and carries the minute hand. On the movement of many watches will be found the words "safety pinion." Most watches at present, whether so marked or not, have one. It means that the center pinion is screwed onto the arbor instead of being rigidly fastened to it. The great advantage is this. When the mainspring breaks (and that is certain to happen sooner or later in every watch) the sudden powerful recoil simply unscrews this pinion and the watch movement escapes injury. If this were not so, teeth might be broken from the barrel, the pivots of the center arbor broken off or bent,

and injury to the escapement might also result. The ratio of the teeth on the center wheel to the leaves on the pinion of the third wheel is 8 to 1, so that the third wheel turns in seven and one half minutes. The ratio of the teeth on the third wheel to the leaves on the pinion of the fourth wheel is $7\frac{1}{2}$ to 1, so that the fourth wheel turns in just one minute. Its arbor is prolonged through the dial and carries the second hand. The ratio of the teeth on the fourth wheel to the leaves on the pinion of the escape wheel is usually 10 to 1, so that the escape wheel turns in six seconds. We have now left the transmitting mechanism and come to the controlling mechanism.

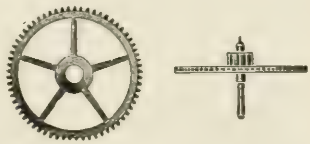


FIG. 66. — A TYPICAL CENTER WHEEL AND A WHEEL AND PINION ATTACHED TO AN ARBOR.

(The Dueber-Hampden Watch Co.)

It may be stated as a summary that the transmitting mechanism consists of three arbors, each carrying a wheel and pinion. Its purpose in a watch is to receive the power from the going barrel and to transmit it to the escape wheel. Each successive wheel turns with greater speed and less power than its predecessor. Incidentally two of the arbors are prolonged through the dial to become the points of attachment of the indicating mechanism.

The controlling mechanism is sometimes called simply the escapement and it is the most delicate and complicated part of a watch. Its function is to allow a watch to run just so fast and no faster. There are four kinds of escapements used in modern watches. These are "the detached lever," "the cylinder," "the duplex," and "the chronometer" escapements. Every American watch today has a detached lever escapement. Some of the others have been used in American-made watches and are still used in foreign watches. They will be considered in a later chapter. It will be assumed in this chapter that the watch has a detached lever escapement.

The controlling or governing mechanism consists of the escape wheel, the detached lever which is usually called the

pallets and fork by jewelers and watchmakers, and the balance staff or arbor which carries the balance wheel, the balance spring, and one or two rollers. These parts are pictured individually in Fig. 67: (*a*) is the escape wheel, (*b*) the escape wheel enlarged, (*c*) the pallets and fork, natural size, (*d*) pallets and fork much enlarged, (*e*) a balance staff, (*f*) a balance staff much enlarged, (*g*) a balance wheel, (*h*) a balance wheel much enlarged, (*i*) and (*j*) two

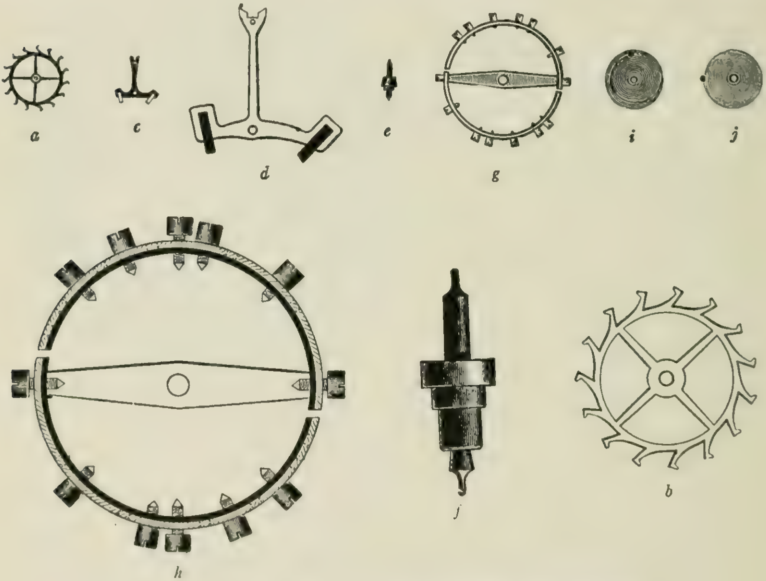


FIG. 67. — THE INDIVIDUAL PARTS OF THE ESCAPEMENT.

kinds of balance springs. Since all the parts operate together in controlling the running of a watch, it will be best to describe the construction of each part first, and then to consider the method of operation of the whole.

The escape wheel usually has 15 teeth and is made of brass, steel, or aluminum bronze. The teeth are called "club" teeth and have a peculiar form. Their sides are not radial and their faces are not tangential (see Fig. 67). It will be remembered that the escape wheel turns in six

seconds and is driven by the transmitting mechanism. The lever is pivoted near its center and swings backward and forward. The limits of its motion are determined by the pins placed in one of the plates and called banking pins. It is usually so arranged that these pins can be moved a little nearer to or farther away from the lever. The lever carries at one end the pallet jewels or pallet stones. In good watches they are either rubies or sapphires and are set into or shellacked to the lever. They are cut to have a perfectly definite form. At the other end of the lever is the fork.

The balance staff is made of steel and carries from the top down (that is, from the back of a watch towards the dial) the balance spring, the balance wheel, and one or two rollers, depending upon whether it is a single roller or a double roller escapement. The difference is very slight and it will be assumed here that we have to do with a double roller escapement. The balance spring, or hairspring as it is often called, consists of about fifteen coils, one outside the other. The inner end is fastened to the "collet" or hub, which is fastened to the balance staff. The last or outer coil passes between the curb pins which, by being moved, enable one to regulate a watch, that is to make it go a little faster or a little slower. The outer end of the hairspring is fastened to a stud in the watch plate. There are two kinds of hairsprings, — flat hairsprings and Bréguet or overcoil hairsprings. In the first case the hairspring coils all lie flat in one plane. In the case of the Bréguet spring the last coil is brought up and over the rest. The two kinds are shown in Fig. 67 (*i*) and (*j*). The two advantages of a Bréguet spring are that there is less danger of the coils being caught in the regulator pins if the watch is violently jarred and secondly the adjustments which will be mentioned later can be made a little more perfectly. Hairsprings are made of tempered steel.

A balance wheel consists of an inner rim of steel to which is fused an outer rim of brass. The rim is cut through in two places near the arms of the balance and there are a

number of screws which are inserted in the rim. It will be noticed that four of these screws (at the four quarters) have shorter heads and are not screwed in as far as the rest. The reason for this particular and unexpected construction of a balance wheel will be explained later. The upper roller is a circular disc which is attached firmly to the balance staff and carries near its outer margin a jewel pin. This is usually a ruby or sapphire and is cylindrical in shape

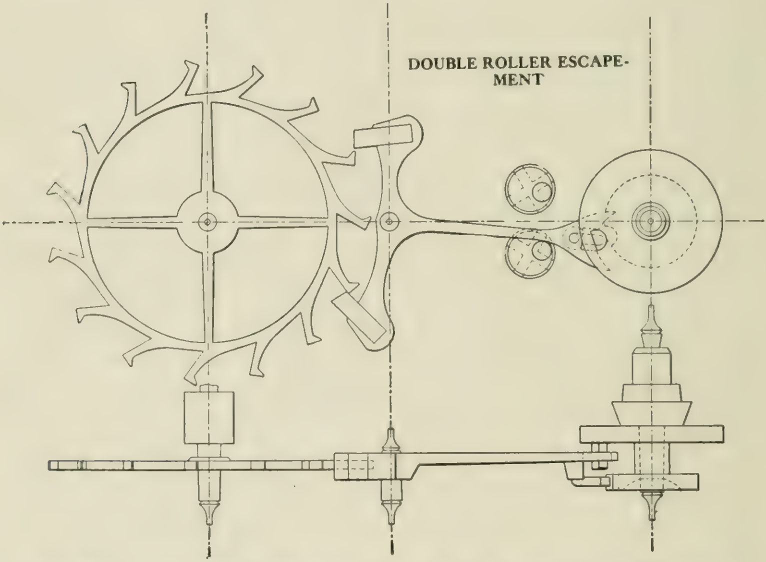


FIG. 68. — HORIZONTAL AND VERTICAL SECTION OF A DOUBLE ROLLER ESCAPEMENT.
(The Waltham Watch Co.)

except that the outer side has been flattened off and the sharp corners removed. This roller jewel is either cemented to or inserted in the roller. The lower roller is a circular disc from which a semicircular portion has been cut away. The roller for carrying the jewel pin is usually of bronze and the lower roller of steel.

The construction of the individual parts of an escapement has now been considered. It remains to explain how

the various parts are fitted together and operate to control the rate of running of a watch. Fig. 68 gives a horizontal and vertical sectional view of a double roller escapement. Fig. 69 is useful in explaining the action of an escapement. In Fig. 69 (*A*) the balance wheel (not shown), together with the roller and roller pin, are just commencing their excursion to the right. The jewel pin is just leaving the fork and for the rest of the trip the balance and attachments will be entirely detached from and independent of the lever. For this reason it is called a detached lever escapement. The escape wheel is firmly locked and kept from turning by the pallet jewel at *N*. The balance wheel will rotate a certain distance and will finally be brought to rest by the hairspring, which is offering ever increasing resistance. The balance wheel will then commence its return trip. Eventually the jewel pin will again enter the fork and carry the lever over towards the left. The tooth of the escape wheel at *N* will be released and, as the escape wheel starts to turn, the face of the tooth will give an impulse to the pallet jewel which will pass it along to the fork and jewel pin and eventually the balance wheel. It is these impulses which keep the balance moving. The lever will now be moved over until it is stopped by the banking pin and has come into the position shown at *B*. The escape wheel has only turned a little way because another tooth has been caught at *M*. The roller jewel now leaves the fork again and goes on a free excursion to the left, eventually to be stopped by the hairspring and forced to return. It again enters the fork, releases a tooth at *M*, and gets an impulse. The lever

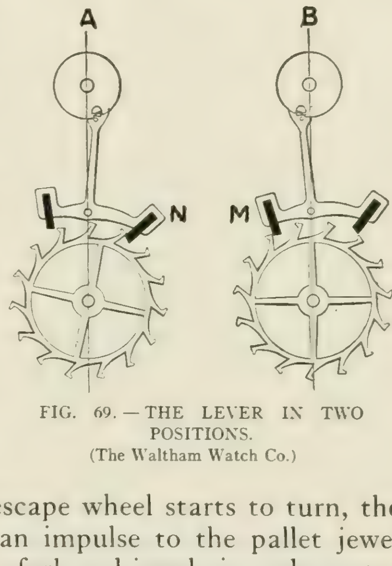


FIG. 69. — THE LEVER IN TWO POSITIONS.
(The Waltham Watch Co.)

goes over to the position shown at *A* and the cycle of the operations is complete. This takes place in every watch 9000 times an hour! The time of a complete swing backward and forward is usually two fifths of a second. The interval between the ticks of a watch which represents a single swing is one fifth of a second. The lower roller and the projecting tongue constitute the "safety action." It is to prevent the lever from being so displaced by a sudden jar to the watch that the roller pin on its return from a free excursion will not be able to enter the fork as it should. Fig. 68 will now make clear the construction of the various parts and show how they are related to each other.

To regulate a watch means to make it run a little faster or a little slower. This is accomplished either through the hairspring or through the balance wheel. Most watches are regulated by changing the effective length of the hairspring. It will be remembered that the last coil of the hairspring passes between two curb pins which should hold it fast but not pinch it. The curb pins are fastened to a rod which is pivoted at one end and can be moved backward and forward by small amounts. By moving this regulator, as it is called, the length of the hairspring in use is changed and thus a watch is made to go faster or slower. All this is well shown in Fig. 70. Some watches have no regulator and curb pins. These are called "free sprung" watches and there is the theory that they can be adjusted somewhat

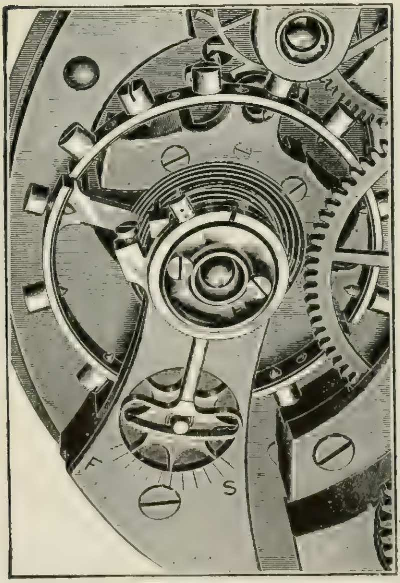


FIG. 70. — THE REGULATOR OF A WATCH.
(The Waltham Watch Co.)

better. If this is the case, then the watch must be regulated by turning the quarter screws in the rim of the balance wheel. To turn them out makes a watch go slower. This can only be done by a jeweler or a very experienced person.

The indicating mechanism consists of the hands and dial and the under-the-dial mechanism, or motion work. It will be remembered that the arbors of the center wheel and the fourth wheel were prolonged through the dial. The second hand is fitted directly to the arbor of the fourth wheel and is simply held on by friction. It can be pulled off and in fact is simply pulled off when a watch movement is taken down by a jeweler. Over the arbor of the center wheel which comes to the center of the dial is fitted friction tight the so-called "cannon pinion." This is a hollow tube perhaps remotely resembling a cannon which carries the minute hand at one end and the teeth of a cogged wheel at the other. These drive a wheel on a stud to which is attached another wheel which drives what may be called a second cannon pinion which is a much shorter tube and fits friction tight over the first. This carries the hour hand and these wheels are known as the under-the-dial mechanism. Their purpose is to move the hour hand one twelfth as fast as the minute hand. These two cannon pinions are fitted friction tight and not rigidly connected to enable a watch to be set. Watches were formerly set by means of a watch key, but now practically all watches are stem-setting. If a watch is set by means of a key, the cannon pinion is usually prolonged slightly and has a square end over which the watch key fits. If a watch is stem-setting, then before turning the stem it must be pushed in or pulled out or a lever at the side of the watch must be pulled out or pushed in. In the first case it is called a pendant-set watch and in the second case a lever-set watch. In either case the operation is exactly analogous to the shifting of gears in an automobile. The wheels connected with the stem are disconnected from the winding wheels and connected through an intermediary with the under-the-dial mechanism.

In the case of a stem-winding and stem-setting watch

the mechanism connected with the stem might almost be considered a fifth group of parts. It consists, as we have already seen, of the wheels connected with the stem, two steel winding wheels, and one intermediary wheel for setting. There must also be a gear-shifting device. The stem wheels are constantly connected with the winding wheels so that a watch is always ready to be wound. When it is to be set these must be disconnected and the intermediary for setting thrown into gear. Since there are quite a few forms of this mechanism, no one will be illustrated.

The materials used. — The four groups of parts into which a watch movement may be divided have now been considered in detail. Altogether there are between 150 and 200 individual parts in a modern watch. Here each tiny screw is of course counted as a separate part. It may be interesting as a review to consider the materials of which these various parts are composed.

Steel is used for all screws; for the mainspring, hairspring, click spring and all other springs; for all pinions and arbors; for the inner rim of the balance wheel; for the two winding wheels; for all clicks; and for all levers. Steel is sometimes used for the mainspring barrel and the lower roller on the balance staff.

Brass is used for the watch plates or bridges; for the wheels; and for the outer rim of the balance wheel. Gold is sometimes used for balance screws; for curb pins; for the mountings of jewels; and occasionally for some wheels. Nickel alloy is often used for the plates and bridges. Aluminum bronze is sometimes used for the wheels; for the lever; and for the rollers.

Jewels. — The word "jewels" is a magic one in connection with watch movements. They are probably more talked about and less understood than any other part. In the popular mind the number of jewels has become inseparably associated with the accuracy of a watch. In general it is correct, but yet it is not necessarily so. A poorly adjusted watch with 21 jewels is much inferior to a 17-jewel

watch which has been carefully adjusted. Usually the care expended on the construction of a watch movement is in rough proportion to the number of jewels, so that they do serve in a general way as an index of the goodness of a watch.

Historically jewels were first introduced into watches by Facio (or Facie) in 1700 or a few years later. The number used has steadily increased. Not so many years ago no American watch had more than 15, and this was considered a fully jewelled watch. At present the largest number is 23 and the smallest number, in a watch considered to be jewelled, is 7. A watch movement selling for less than $3 when new or a complete watch selling for less than $5 usually has no jewels at all. Diamonds, sapphires, rubies, and garnets are used for the jewels. It is sometimes said that the cheapest jewels are nothing but glass. As one writer puts it: "Very common watches have glass, most watches have garnets, and only a very few of the best ones have rubies and sapphires."

The purpose of jewels is to lessen the friction and increase the regularity of running of a watch. The arbors or axles which carry the wheels and pinions or other moving parts have their ends made somewhat smaller to form pivots. These may be tapering or simply reduced in size, thus forming a shoulder. If there were no jewels, then these pivots would run in holes in the watch plates. So-called hole jewels are used with these pivots. That is, a small hole is bored in a ruby or garnet and these jewels are then set in the watch plates in such positions that the pivots run in the holes. Formerly jewels were fastened in watch plates by being burnished in. Now each is placed in a little round setting of low-carat gold and then is fastened to the watch plates by means of two tiny screws. The faster moving pinions often have cap jewels or end stones as well as hole jewels. This means that a flat plate is placed over the hole jewel. If a watch is lying on its side, the pivots would go through the holes in the jewels until held by the shoulder. The end stone prevents this because the end of the pivot comes in contact with it. In Fig. 301 is

illustrated the arrangement of a hole jewel and end stone. There are usually three sapphire jewels in the escapement. These are the two pallet jewels and the roller jewel.

If a watch has 23 jewels, then the going barrel, the center wheel, the third wheel, the fourth wheel, the escape wheel, the lever, and the balance have a hole jewel at each end of each arbor. This makes 14. The balance, the lever, and the escape wheel have end stones as well. This adds 6 more. Then there are 3 jewels in the escapement. This makes 23. If a watch movement has 21 jewels, then it is the hole jewels of the going barrel which have been omitted. If a watch has 19, then the end stones of the escape wheel have been omitted also. If there are 17 jewels, then the end stones of the lever have probably been omitted also. If a watch has only 7 jewels, these usually consist of the three escapement jewels, and two hole jewels and two end stones for the balance arbor.

Jewels are not as expensive as one might expect. The best and largest jewel for a fine watch would not cost far from $1 and small cheap jewels only a few cents.

The three adjustments. — Good watches are adjusted to isochronism, to temperature, and to several positions. These are only mystic words to the average possessor of a watch and mean in plain language that the watch movement has had care expended on its construction. The exact meaning of these three adjustments will now be considered in detail.

If a watch has just been wound up the mainspring is pulling with its greatest force. This is transmitted through the time train until it is finally communicated to the swinging balance wheel and causes it to turn through a larger arc. Perhaps, to give an illustration, the balance swings through $1\frac{1}{2}$ turns when the watch is just wound up and only one when nearly run down. There are other things, too, which may change the arc of swing of the balance. Perhaps the oil thickens. This would introduce more friction and thus consume power and reduce the arc. Perhaps a particle of dirt gets into a bearing and introduces considerable

friction. Perhaps the watch is put in a colder place. The mainspring then pulls with greater force and the arc increases. There are a multitude of happenings in the everyday life history of a watch which may change the force communicated to the balance and thus its arc of swing.

To adjust a watch to isochronism means to so adjust the hairspring that the time of swing of the balance will be the same whether it swings through a large arc or a small one. It will be remembered that one end of the hairspring is fastened to a hub or collet on the balance staff; that there are some 14 or 16 coils; that the outer coil in a Bréguet spring is brought up and over the rest; that the last coil passes between the curb pins of the regulator; and that the outer end of the hairspring is fastened to a post in the watch plate or bridge. The hairspring is adjusted to isochronism by changing the shape of the initial and terminal curves, that is, its shape is changed near the collet or near the curb pins. To say that a watch is adjusted to isochronism really means that the hairspring has been so adjusted that it and all the swinging parts associated with it oscillate in the same time regardless of the arc through which the balance turns. Many pages have been written taking up the form of the curves which the ends of the hairspring ought theoretically to have. In practice watch adjusters do it almost by instinct.

A change of temperature affects a watch in many ways. If the temperature rises, the oil becomes thinner and the friction changes. The wheels and pinions also expand so that the faces which come in contact with each other are slightly different and thus the friction is altered. The mainspring also has less resilience. If, however, a watch has been perfectly adjusted for isochronism these results of a temperature change will have no effect on the rate of running of the watch. But a temperature change also causes the balance wheel to expand or contract and changes the resilience of the hairspring and these results will profoundly influence the rate of running. For this reason all the good modern watches have the so-called compensated

balances. It will be remembered that the balance consists of an inner rim of steel and an outer rim of brass welded together; that the rim is cut through in two places; and that there are many screws in the rim with provision for changing their location. If the temperature rises, the balance expands, but the brass rim expands more than the steel and thus the tips of the free segments curl in. If the balance has been correctly compensated, this curling in counteracts the expansion of the balance and the changes in the hairspring and the time of the swing remains the same. This is tested by placing a watch movement in cold and then in heat. If it runs more slowly in heat it is undercompensated and a pair of screws must be moved nearer the tips of the free segments. A watch is thus adjusted to temperature by changing the position of the screws in the rim of the balance wheel.

It has been assumed in the present chapter that a watch always has a bimetallic balance wheel composed of steel and brass. This is true of practically all American factory-made watches. In the case of European watches of precision a "Guillaume" balance is generally used. Here an alloy of nickel and steel has replaced the steel and the temperature compensation is a little more exact. In very recent times in a few of the finest watches a solid, uncut, integral balance wheel is used which is composed of an alloy recently discovered by Ch.-Éd. Guillaume of Paris, which changes extremely little with temperature changes. More will be said about this in Chapter XIV on "The History and Construction of the Individual Parts of Watches."

A watch is also adjusted to position. This means that the rate of running must be the same in many positions. A good watch is usually adjusted to five positions. These are flat with dial up, flat with dial down, on edge stem up, on edge stem to right, on edge stem to left. These positions are shown in Fig. 71. One watch factory adjusts its best watches to six positions; the sixth being on edge, stem down. Sometimes good watches are adjusted to only three positions. If a watch is on edge the pivots are running

on one side of each hole jewel. If it is flat then all the weight of the wheel, pinion, and arbor comes on one jewel. The friction will be quite different in these two cases, but if the isochronism adjustment has been well made there ought to be no change in the rate of running of the watch. This would seem to be the correct theoretical conclusion, yet many practical watch adjusters affirm that the faults in the train and other parts of the movement besides the balance will cause position errors. The balance wheel may, however, not be perfectly poised. This means that the center of mass may not coincide with the center of figure. If this is true, then position will decidedly affect the rate of running. To be sure, balances are all carefully poised before they are put into watches, but they are poised before the collet and hairspring are attached, and this may destroy the poise. Adjustments to position are made by turning (one in, the other out) a pair of opposite screws in the rim of the balance wheel.

FIG. 71. — THE FIVE POSITIONS IN WHICH A WATCH IS ADJUSTED.

(The South Bend Watch Co.)

A magnificent watch. — This chapter may well end with a description of the most expensive watch made in the United States. It is the "Premier Maximus Certificate Watch," made by the Waltham Watch Co., of Waltham, Mass., and selling for $750. It is by far the most expensive watch made entirely in this country.[1] Next to it come watches priced at something less than $300. The price includes an ordinary solid gold case as well as the movement. Of course by ornamenting the case and decorating it with jewels the cost of a watch (case and movement) may be carried to

[1] Until quite recently the E. Howard Watch Works at Waltham, Mass., did the same thing and very lately (1922) the Elgin National Watch Company at Elgin, Ill., has put out a similar watch.

almost any figure. It is 16-size and the claim is made by the maker that it is the equal, if not the superior, of any watch made in the world. The technical description, taken from the advertising literature, will illustrate many points in this chapter. It is pictured in Fig. 72.

Description

Twenty-three Diamond, Fine Ruby and Sapphire Jewels; Three Pairs Diamond Caps, Raised Gold Settings; Balance, Pallet and Escape Pivots running on Diamonds; Jeweled Mainwheel Bearings; Red Gold Caps on Pallet, Escape and Fourth Bridges; Accurately Adjusted to Temperature, Isochronism, and Five Positions, and carefully timed in its case at the factory; Compensating Balance, Mean-time Screws; Patent Bréguet Hairspring Hardened and Tempered in Form; Patent Detachable Balance Staff; Bronze Train; Double Roller Escapement; Sapphire Jewel Pin permanently driven into the roller; Recessed Steel Escape Wheel with Gold Hub; Exposed Red Ruby Pallets; Tempered Steel Safety Barrel; Patent Micrometric Regulator; Steel Parts Highly Finished with Rounded Polished Corners; Patent Winding Indicator showing on the dial the number of hours, up to twenty-four, the watch has run since last winding; Fine Glass Hand-Painted Dial of the most modern and artistic design.

FIG. 72.—THE FINEST WATCH MADE IN AMERICA.
(The Waltham Watch Co.)

CHAPTER IX

THE HISTORY OF SPRING-DRIVEN CLOCKS AND CLOCK-WATCHES FROM 1500 TO 1658

The invention of the mainspring is usually ascribed to Peter Henlein, a locksmith of Nürnberg, who was born about 1480 and died in 1542. The name is variously given by different writers as Heinlein, Henle, or Hele, but in the list of Nürnberg locksmiths the spelling is Henlein. In 1500 or a few years later he used a long, tightly coiled ribbon of steel as the driving power instead of the weight which had always been used up to this time. Bürgel in his *Astronomy for All* quotes these comments which appeared in the *Cosmographia Pomponii Melae*, published in Nürnberg in 1511. "Every day finer things are being invented. Peter Hele, still a young man, has constructed a piece of work which excites the admiration of the most learned mathematicians. He shapes many-wheeled watches out of small bits of iron, which run without weights for forty hours, however they may be carried, in pocket or chemisette." This marks a decided epoch in the history of clock-making. The weight-driven clocks were not portable, but the spring-driven ones were and these new curiosities immediately appealed to the very wealthy. There are but very few specimens in existence of these new clocks, or clock-watches as we shall call them.

The early clock-watches were probably cylindrical boxes, that is drum-shaped, and several inches in diameter. The dial was of brass, chased or engraved, usually heavily gilt, and there was only one hand. It might perhaps be mentioned in passing that the difference between chasing and engraving is this: If an object is chased, then the

FIG. 73. — AN EARLY UNNAMED CLOCK-WATCH, FROM THE SOLTYKOFF COLLECTION.
(From DUBOIS, *Collection Archéologique du Prince Pierre Soltykoff.*)

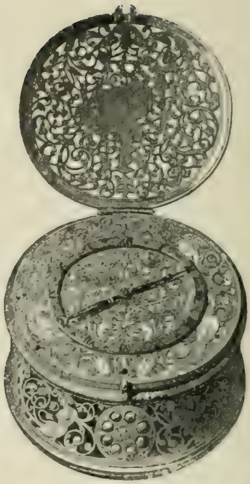


FIG. 74. — AN EARLY CLOCK-WATCH, BY CHARLES CUSIN, OF AUTUN, DATE ABOUT 1575.
(From DUBOIS, *Collection Archéologique.*)

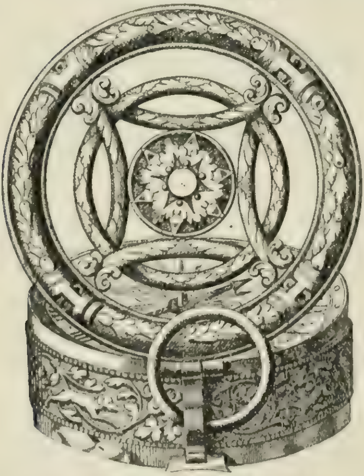


FIG. 75 — AN EARLY CLOCK-WATCH, FROM THE SOLTYKOFF COLLECTION.
(From DUBOIS, *Collection Archéologique.*)

FIG. 76. — A CLOCK-WATCH MADE BY HANS GRUBER, OF NÜRNBERG AND DATED 1560.
(South Kensington Museum, London.)

pattern has been made by rubbing, pounding, or pressing either from the front or under side. If it is engraved, then the material has been cut away to form the pattern. The cover was of brass deeply engraved and usually pierced so as to show the hour marks and hand underneath. Thus the time could be determined without opening the case. These cases were usually hinged, although sometimes they were pressed or snapped on. The works were of iron or steel. No screws were used and the parts of the movement were held together by pins and wedges. The driving mechanism, as has been said, was a long ribbon of steel, in other words, a mainspring. The controlling mechanism was the foliot balance, the verge, and crown wheel. This was the controlling mechanism in all timekeepers until 1658. As the years passed brass was occasionally used for the wheels and plates and screws made their appearance not long after 1550.

Seven of these early clock-watches are illustrated in Figs. 73 to 79. The one illustrated in Fig. 73 was in the Soltykoff collection. (See Appendix III for museums and collections.) It is unnamed, but doubtless of German origin, perhaps made in Nürnberg. It dates from the first half of the sixteenth century. It is both a striking and alarm watch. It has a brass gilt case, with twenty-four openings in the cover for determining the position of the hand when the case is closed. There are also knobs at the hours for telling the time by feeling at night.

The clock-watch pictured in Fig. 74 was also in the Soltykoff collection. It is a striking watch with a silver hour circle and a blued steel hand. It is by Charles Cusin, who was born at Autun in Burgundy and later settled in Geneva. It dates from about 1575.

The clock-watch pictured in Fig. 75 was also in the Soltykoff collection. It is an early sixteenth-century production and has a cover somewhat different from that ordinarily used. It is unnamed.

The clock-watch pictured in Fig. 76 is in the South Kensington Museum in London. It was made by Hans Gruber of Nürnberg in 1560. This skillful maker was master of the locksmiths' guild in 1552 and died in 1597.

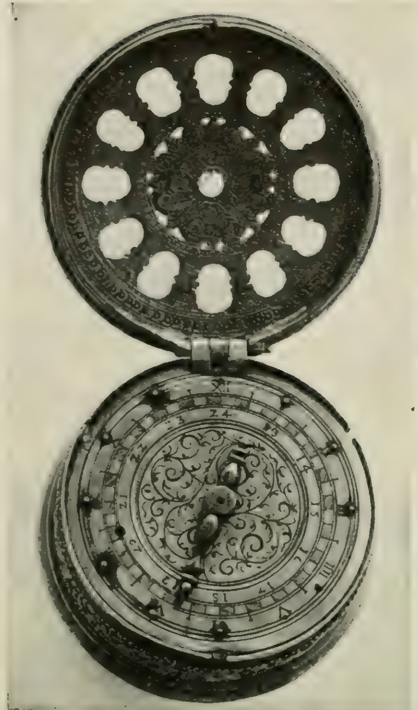


FIG. 78.—AN EARLY CLOCK-WATCH IN THE MORGAN COLLECTION IN THE METROPOLITAN MUSEUM OF ART IN NEW YORK CITY.

FIG. 77.—A CLOCK-WATCH IN THE BRITISH MUSEUM, BY JEREMIAS METZGER, OF AUGSBURG.

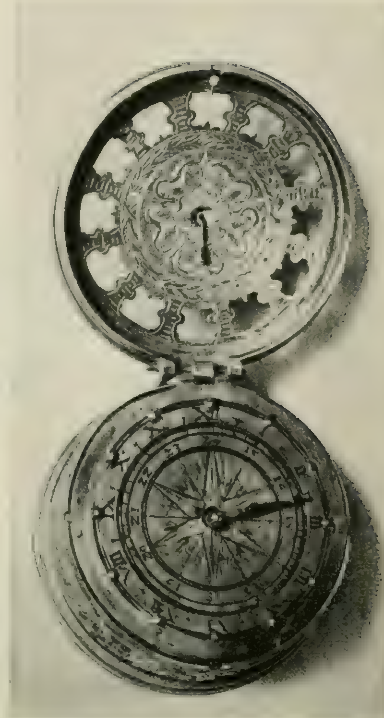


FIG. 79.—AN EARLY CLOCK-WATCH IN THE MUSEUM OF ART IN NEW YORK CITY, MADE BY MICHAEL GRUBER, OF NÜRNBERG.

The clock-watch pictured in Fig. 77 is in the British Museum in London. It is of German make, probably by Jeremias Metzger of Augsburg, and dates from about 1530.

The clock-watch pictured in Fig. 78 is in the J. Pierpont Morgan collection at the Metropolitan Museum of Art in New York City. It is signed A. K. and is an early sixteenth-century production. It is $2\frac{1}{2}$ inches in diameter.

The clock-watch illustrated in Fig. 79 is in the Metropolitan Museum of Art in New York City, loaned by Maurice M. Sternberger. It is a striking watch in a brass case and was made by Michael Gruber at Nürnberg about 1600.

The stackfreed and fusee. — These clock-watches were not good timekeepers. In fact the use of a mainspring introduced a serious error. The mainspring when wound up pulled hard and when nearly run down pulled with much less force. With the old verge escapement, this profoundly influenced the rate of running. The first invention to counteract this was the "stackfreed," which is shown in Fig. 80. It consisted of a strong curved spring and cam. When the mainspring was wound up and pulled with its greatest force the stackfreed spring had to be raised from the curved depression in the cam and this lessened the power of the mainspring. Later when the mainspring was nearly run down the end of the stackfreed spring by falling into the curved depression in the cam furnished a small amount of additional power. It thus served to equalize to a certain extent the very unequal pull of the mainspring. The origin of the word stackfreed is unknown; it may be a Persian word.

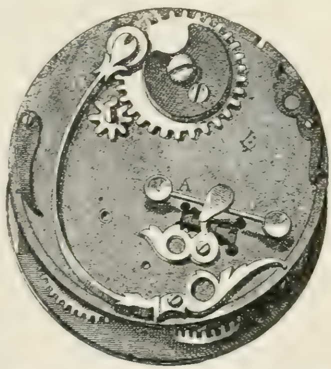


FIG. 80.—A STACKFREED AND FOLIOT BALANCE.
(From Dubois, *Collection Archéologique.*)

The movement pictured in Fig. 80 is from the clock-watch illustrated in Fig. 75. It will also be noticed that the foliot balance consisted of a bar with two discs at either end. It had not yet become a balance wheel.

The next device for equalizing the pull of the mainspring was the fusee. This was invented by Jacob Zech of Prague in 1525. It is pictured in Fig. 81 and consists of a cone-shaped pulley *b* upon which is wound a cat-gut cord *c*. The other end of the cord is wound around the outside of the barrel *a* which contains the mainspring. One end of the mainspring is fastened to a fixed central arbor, while the other end is fastened to the inside of the barrel which rides free on its arbor. The main driving wheel is attached to the fusee and the timekeeper is wound by turning the fusee and this winds the cord on to the fusee and off of the barrel. As the timepiece runs, the spring turns the barrel, winding the cord on it and thus causing the fusee to rotate. The fusee equalizes the pull of the mainspring by being conical. When the mainspring is pulling hardest the cord is on the smallest part of the fusee and thus pulling with the smallest leverage. By shaping the fusee to suit the mainspring, its pull can be made uniform. This was a great improvement and was widely used. At present it is still used in all chronometers, in many of the best spring-driven clocks, and in a few foreign-made watches. In the modern pocket watch the fusee is unnecessary because the hairspring has been adjusted to isochronism and furthermore a long spring is used so that only the first three fifths of its expansion is ever used. In the early clock-watches the cat-gut cord was always used. Gruet, a Swiss, introduced chains instead of cat-gut in 1664 and a flexible chain is always used at present.

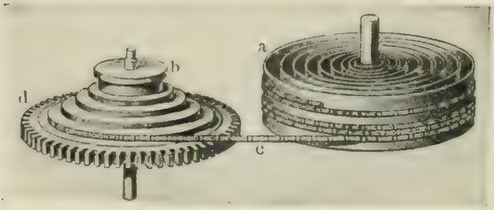


FIG. 81. THE FUSEE.

The evolution of the early clock-watch. — As the years passed, the original clock-watches developed along two entirely different lines. On the one hand they became smaller, then oval in form, then very ornate and of many shapes, and finally about 1600 they became the pocket watch. (See Chapter XIII.) On the other hand, they became larger and square or hexagonal in form. Later they were quite high and very elaborate. In other words, they became the elaborate, intricate, spring-driven table clocks which, particularly in Germany, had their period of greatest development about 1600 or a little later. Both of these lines of development deserve a more detailed treatment.

The table clock. — The designation table clock is ordinarily used for these clocks. It signifies that a table was the customary and more usual location. These table clocks could have been placed on a mantel, on a shelf, or on a pedestal and thus called mantel clocks, or shelf clocks, or pedestal clocks. There are also many other kinds of clocks which could be placed on a table. Similar ambiguities are always possible with such designations as shelf clock, bracket clock, mantel clock, pedestal clock, wall clock, and the like. Table clock is, however, the more usual designation for these clocks and the term is ordinarily reserved for this kind of clock only. It will be so used and only so used in this book.

The first table clocks probably differed but little from the earliest clock-watches — that is, they were cylindrical boxes, only somewhat larger. Then they became square or hexagonal and small feet were perhaps added. Then they grew in height and became more elaborate, until finally they became the very intricate table clocks. Still later the elaborate ornamentation of the case became almost grotesque. Eight of these table clocks are pictured in Figs. 82 to 89.

The first one (shown in Fig. 82) was in the collection of Prince Soltykoff and the illustration is taken from Dubois' magnificently illustrated book: *Collection archéologique du Prince Pierre Soltykoff.* The case is square and the sides

are of bronze, heavily gilt. In the center of each side is a silver medallion representing St. Paul, Matthew, Mark, and Luke. It is a striking clock with the bell in the dome and has a horizontal dial at the top. It was the work of Louis David and dates from a little later than 1550.

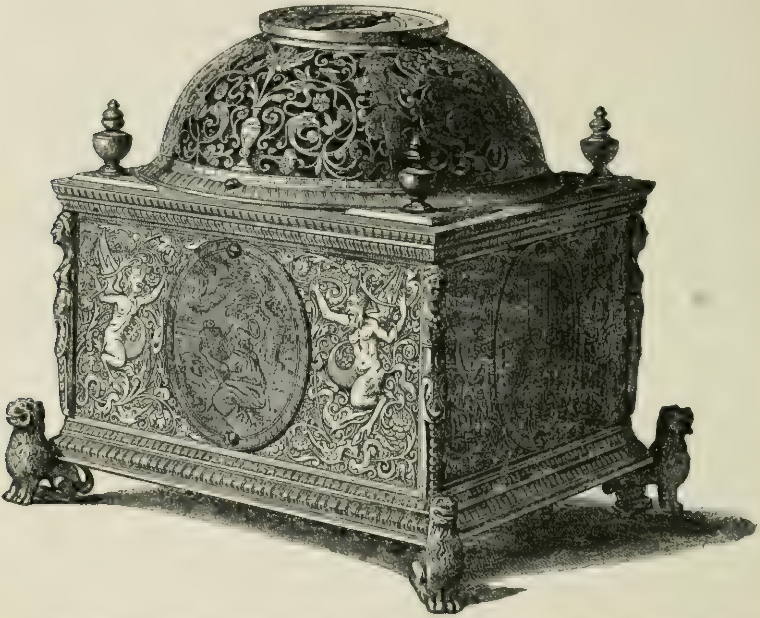


FIG. 82. — A TABLE CLOCK OF THE SIXTEENTH CENTURY, BY LOUIS DAVID.
(From Dubois, *Collection Archéologique.*)

The next four (Figs. 83 to 86) are in the British Museum in London. The first is an horizontal, striking clock, German, about 1600. The next is a striking clock with circular balance, French, about 1540. The case is stamped B. Couldroit. The third is an elaborate clock by Lucas Weydman of Cracow, dated 1648. The fourth is German, about 1600, and rather grotesque. The globe turns and thus indicates the hour. As the clock strikes the dog jumps.

FIG. 83. — AN HORIZONTAL CLOCK, GERMAN, ABOUT 1600, IN THE BRITISH MUSEUM.

FIG. 84. — A STRIKING CLOCK, FRENCH, ABOUT 1540.
(The British Museum.)

FIG. 85. — AN ELABORATE CLOCK, BY LUCAS WEYDMAN, OF CRACOW, DATED 1648.
(The British Museum.)

FIG. 86. — A TABLE CLOCK WITH REVOLVING GLOBE.

FIG. 87. — AN ELABORATE TABLE CLOCK, GERMAN (AUGSBURG), ABOUT 1560, IN THE SOUTH KENSINGTON MUSEUM.

FIG. 88. — AN HEXAGONAL TABLE CLOCK.
(The British Museum.)

FIG. 89. — A TABLE CLOCK OF THE SIXTEENTH CENTURY, IN THE MUSEUM OF ART IN NEW YORK CITY.

The next two (Figs. 87 and 88) are in the South Kensington Museum in London. The first is an elaborate clock, German (Augsburg), about 1560. It is $11\frac{1}{2}$ inches high and $6\frac{3}{4}$ inches wide. The second is an hexagonal clock, German, sixteenth century. It is $5\frac{3}{8}$ inches high and has a diameter of $3\frac{3}{8}$ inches.

The last one (Fig. 89) is in the Metropolitan Museum of Art in New York City, lent by Maurice M. Sternberger. It is a sixteenth-century German production. The figure points out the time with a sword.

FIG. 90.—A TRANSITIONAL SIXTEENTH-CENTURY WATCH.

(The Metropolitan Museum of Art.)

The development of the pocket watch. — The early clock-watch of 1500 developed into the pocket watch in about one century. At first the clock-watch became a little smaller with rounded edges, then it became elongated and octagonal or oval. These oval watches are often spoken of as "Nürnberg eggs." Four of these transitional clock-watches are illustrated in Figs. 90 to 93. The first three are in the Metropolitan Museum of Art in New York City, a part of the J. Pierpont Morgan collection. The last

FIG. 91.—AN EARLY OCTAGONAL WATCH.

(The Metropolitan Museum of Art.)

FIG. 92.—AN OVAL WATCH, BY GAILLAIRD, OF LYONS, DATE ABOUT 1590.

(The Metropolitan Museum of Art.)

FIG. 93.—AN OVAL WATCH, BY PIERRE COMBET, OF LYONS.

(From DUBOIS, *Collection Archéologique*.)

one was in the Soltykoff collection. The first one (Fig. 90) is a sixteenth-century production in a richly engraved and pierced case, 2½ inches in diameter. It is a striking watch and the border is pierced to allow the escape of the sound from the bell. The second (Fig. 91) is a German production in an octagonal case 2½ by 1⅝ inches. The lid is of rock crystal. It has a silver dial with a gilt metal numeral ring. The third (Fig. 92) is the work of N. Gaillaird of Lyons and dates from about 1590. The fourth (Fig. 93) is the work of Pierre Combet of Lyons and is of about the same date. A cruciform watch by this maker is in the Morgan collection in New York and there is a watch by him in a shell-shaped case in the South Kensington Museum in London.

Although these shapes were better for a pocket watch, still they were too large and as a matter of fact were never carried in the pocket.

Somewhat later comes the strong desire for watches of unusual and artistic form. Thus before 1600 we find watches having the form of books, animals, fruit, stars, flowers, insects, padlocks, crosses, and cockle-shells. A few simulated a skull, the so-called death's head watches. Gold, silver, and rock crystal were now used even more than brass, and the cases were often set with precious stones. These watches were fastened to the clothing or suspended from a chain around the neck. They were never carried in the pocket. These watches of unusual form were often called toy watches and continued to be made until 1800 or even later.

Six of these are illustrated in Figs. 94 to 99. The first four are in the J. Pierpont Morgan collection in the Metropolitan Museum of Art in New York City. The last two were in the Soltykoff collection. The first (Fig. 94) is the work of Nicolas Bernard of Paris and is 1½ by 1¼ inches. The case is of rock crystal and it dates from about 1590. There are two watches bearing the same name in the South Kensington Museum in London. The second (Fig. 95) is the work of Conrad Kreizer of Strasbourg and is so signed on the movement. At the end of each bar there is a Mal-

FIG. 94. — A ROCK CRYSTAL OCTAGONAL WATCH, BY NICOLAS BERNARD, OF PARIS, DATE ABOUT 1590.

FIG. 95. — A WATCH, BY CONRAD KREIZER, OF STRASBOURG, IN THE FORM OF A CROSS.

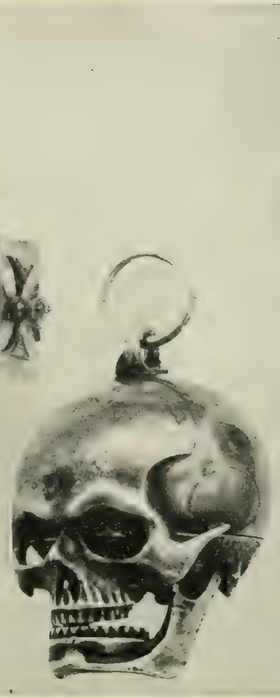


FIG. 97. — A SKULL WATCH, THE WORK OF ISAAC PENARD, OF BLOIS.

FIG. 96. — A WATCH, BY CHARLES CUSIN, OF AUTUN, IN THE FORM OF A CROSS.

tese cross of black and blue enamel. The third (Fig. 96) is the work of Charles Cusin of Autun and is 1½ by 1⅛ inches. The case is of rock crystal and the dial of silver on a face of polished yellow metal. The fourth (Fig. 97) is the work of Isaac Penard of Blois. The lower jaw of the skull opens and reveals the dial. It is 1½ by 1⅛ inches and dates from about 1630. The fifth (Fig. 98) is the work of Rugend of Auch and dates from just after 1600. The dial is of silver. The sixth (Fig. 99) is in the shape of a pear and the work of Conrad Kreizer (Dubois says: Kreitzer Conrat) of Strasbourg. It dates from just before 1600. There is also an octagonal watch by him in the South Kensington Museum, London, and a watch in the form of a cross in the Vienna Treasury.

Just before 1600 a very few small many-sided or circular watches made their appearance. These were more suitable for the pocket, but it was not the fashion to carry them there and furthermore there was usually a projection on the case opposite the stem. The true pocket watch made its appearance about 1600 or a little later, and in a later chapter the history of pocket watches from 1600 to 1800 will be taken up.

The cities famous for clockmakers. — The various countries where these spring-driven timekeepers were made in large numbers during this period should be briefly considered. As was noted at the very beginning of this chapter, the spring-driven timekeeper originated in Nürnberg in 1500. The knowledge of it soon spread to other parts of Germany, and many German cities became famous for their clockmakers. This is particularly true of Nürnberg and Augsburg. The knowledge also spread to France, to Switzerland, and the Netherlands. In France, Blois and Rouen were the two chief centers. The knowledge also came to England, but here comparatively few spring-driven timekeepers, particularly clocks, were made during this period. The favorite clock was of the weight-driven lantern or bird cage form.

Some spring-driven timekeepers were, however, made in

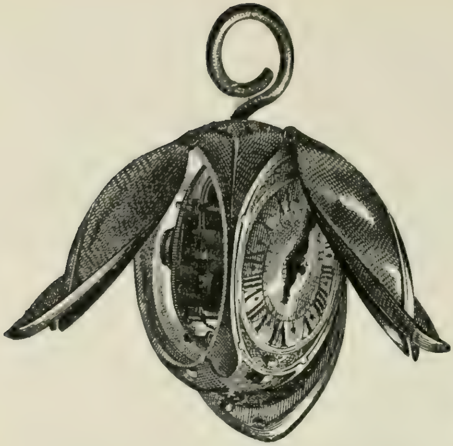


FIG. 98.—A WATCH IN THE FORM OF A TULIP, BY RUGEND, OF AUCH.
(From Dubois, *Collection Archéologique.*)

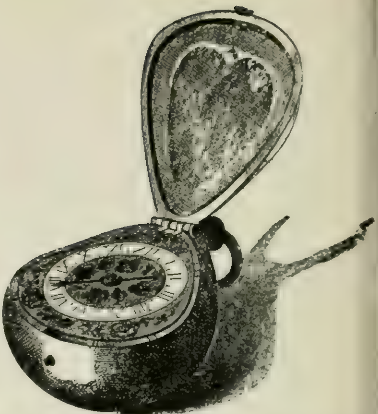


FIG. 99.—A WATCH IN THE FORM OF A PEAR, BY CONRAD KREIZER, OF STRASBOURG.
(From Dubois, *Collection Archéologique.*)

FIG. 100.—A BRASS TABLE CLOCK, BY BARTHOLOMEW NEWSAM, NOW IN THE BRITISH MUSEUM.

FIG. 101.—A TABLE CLOCK, BY NEWSAM, NOW IN THE METROPOLITAN MUSEUM OF ART IN NEW YORK CITY.

England, chiefly in London, during this period. Six of these are shown in Figs. 100 to 105.

In Fig. 100 is pictured a fine brass striking table clock by Bartholomew Newsam. It is $2\frac{1}{2}$ inches wide and $6\frac{1}{2}$ inches high. The case is of brass, engraved and gilded. There is but one hand. The wheels are of steel or iron. There are fusees connected with the brass barrels by cat-gut. There are no screws and the escapement consists of balance, verge, and crown wheel. This clock is now in the British Museum and is inscribed "Bartilmewe Newsum." Newsam was probably a Yorkshire man who later came to London and lived in the Strand near Somerset House. He was clockmaker to Queen Elizabeth and died in 1593.

A table clock and a watch by Newsam also form part of the J. Pierpont Morgan collection in the Metropolitan Museum of Art in New York City and they are illustrated in Figs. 101 and 102. The dome of the clock is pierced to reveal the bell. The dial at the top is of silver and $1\frac{3}{4}$ inches in diameter. The circumference of the clock is 10 inches. The sides are engraved with classical heads separated by foliage. The watch is signed B. N. on the movement and is in a silver twelve-sided case. The dial is of gilt metal with silver numeral ring.

In Fig. 103 is pictured a fine striking watch in a gilt metal case which is signed on the movement "Michael Nouwen, London" and dates from 1590. It is engraved and pierced on the front, back, and sides. On the dial is engraved a figure of Plenty among foliage. It is $1\frac{7}{8}$ inches in diameter. It has a stackfreed and a straight bar balance and no screws have been used in its construction. This watch is also in the Morgan collection. There is also a watch by him in an octagonal case of crystal in the British Museum in London and an oval watch in the Ashmolean Museum at Oxford, England.

In Fig. 104 is illustrated a fine oval watch by Crayle. It is inscribed "Richard Crayle Londini fecit" and is not later than 1610. Richard Crayle was one who signed the petition for the incorporation of the clockmakers' company.

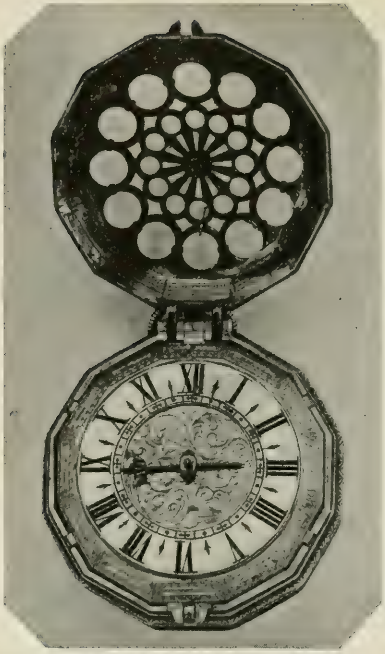


FIG. 102. — AN EARLY WATCH, BY NEW-SAM.

FIG. 103. — AN EARLY WATCH, BY NOU-WEN.

FIG. 104. — AN OVAL WATCH, BY CRAYLE.

FIG. 105. — AN OVAL WATCH, BY EDWARD EAST.

This watch is in the Metropolitan Museum of Art in New York, loaned by Maurice M. Sternberger. There is also a small oval watch by Crayle in the South Kensington Museum, London.

Fig. 105 illustrates a fine oval watch by Edward East. It is signed on the movement "Edwardus East, Londini," and dates from about the middle of the seventeenth century. It has a gilt metal case pierced and engraved in floral designs. This watch is a part of the Morgan collection. East was a well-known maker and there are quite a few watches and clocks by him in existence.

It must not of course be assumed that these four men, Newsam, Nouwen, Crayle, and East, produced all the spring-driven timekeepers which were made in England before 1658. If all the museums, collections, and records were searched, the names of perhaps fifty makers would be found.

One thing is particularly noticeable all through this period. A timekeeper was esteemed primarily on account of its exterior ornamentation or unusual form or on account of its intricate and curious mechanism. Accuracy in keeping time was always of very minor importance.

CHAPTER X

THE HISTORY OF PENDULUM CLOCKS FROM 1658 TO 1800

The invention of the pendulum. — This period begins with a great invention, one destined to almost revolutionize the construction and accuracy of clocks. It was in 1658 or a little later that the pendulum was first used in clocks as a part of the controlling mechanism. As is the case with many of the great discoveries, it is impossible to name any one person as the undisputed inventor. The various claimants for the honor are Jost Bürgi, Richard Harris, Vincenzio Galilei, Robert Hooke, Ahasuerus Fromanteel, and Christian Huygens.

In 1612 or thereabouts, Jost Bürgi (Burgi, Burgk, De Burgi, or Burgius) of Prague constructed a clock provided with a pendulum which is now in the Vienna Treasury. He was born in 1552, in Lichtensteig in Switzerland, died in 1632, and was appointed clockmaker to Rudolph II in 1602. This clock strikes the hours and quarters and shows the day of the week and the phases of the moon. In considering his claim it must be said in the first place that it is extremely difficult to prove that a clock has not been rebuilt or remodeled since it was originally constructed. New works were often placed in old cases. A clock movement when much worn was often reconstructed and new ideas and improvements added without changing the name or date on the movement. Again, even if it could be proved that this clock was constructed in 1612 *in its present form*, it would be only an isolated example, as nothing came of the invention.

Richard Harris is said to have constructed a turret clock with a pendulum for the church of St. Paul's, Covent Garden, in 1641. This church has since been burned. In the vestry-room of the church was an engraved plate af-

fixed by Thomas Grignon a little before 1800 which runs in part as follows: "The clock fixed in the turret of the said church was the first long pendulum clock in Europe, invented and made by Richard Harris of London, A.D. 1641, although the honor of the invention was assumed by Vincenzio Galilei, A.D. 1649, and also by Huyghens in 1657." It would seem that there was a controversy even then as to who invented the pendulum. Even if he did use the pendulum it is again an isolated case and nothing came of it.

As early as 1583 Galileo Galilei had already studied the isochronism of swinging bodies. In 1641 he, when blind, explained to his son Vincenzio (or Vincenzo) and Viviani how a pendulum could be used to control clockwork. In 1649 Vincenzio with others began to carry out this idea of Galileo. He died in 1649, probably before he had finished his experiments. At any rate nothing came of it.

Robert Hooke was born at Freshwater, Isle of Wight, in 1635 and died in 1703. He was a teacher, an inventive genius, and a thinker and writer on most of the scientific questions of his day. We will see a little later that several important inventions are due to him. He probably was working with pendulums at the same time as Christian Huygens.

Ahasuerus Fromanteel (Fromantel, Fromantil, Formantil, or Fromenteele) was of Dutch extraction and lived in England. He is supposed to have been a personal friend of Huygens and to have introduced the pendulum into England. He was a famous clockmaker and several examples of his work are in existence at present.

If the honor of introducing the pendulum into clock mechanism is to be given to any one man, more agree upon giving that distinction to Christian Huygens than to any one else. This great mathematician and scientist was born in Holland in 1629. His birth place seems to have been Zulichem, and this is often used for him almost as a second family name. He produced his first pendulum clock in 1657. In 1665 he was invited to Paris by Louis XIV to found a Royal Academy of Sciences. He returned to

Holland in 1681 and died there in 1695. At Paris in 1673 was published his work: "Christiani Hugenii Zulichemii, Constantini filii, Horologium oscillatorium, sive de motu pendulorum ad horologia adaptato demonstratíones geometricae." This contains drawings and a description of his clock. Evelyn in his diary under date of April 1, 1661, writes: "Dined with that great mathematician and virtuoso, Mr. Zulichem, inventor of the pendule clock." On May 8, 1661, he writes: "I returned by Fromantel's, ye famous clockmaker, to see some pendules, Mr. Zulichem being with us." The *Commonwealth Mercury*, of Thursday, November 25, 1668, contains this advertisement:

There is lately a way found out for making clocks that go exact and keep equaller time than any now made without this regulator (examined and proved before his Highness the Lord Protector by such doctors whose knowledge and learning is without exception), and are not subject to alter by change of weather, as others are, and may be made to go a week, or a month, or a year, with once winding up, as well as those that are wound up every day, and keep time as well; and is very excellent for all house clocks that go either with springs or weights; and also steeple-clocks, that are most subject to differ by change of weather. Made by Ahasuerus Fromanteel, who made the first that were in England. You may have them at his house, on the Bankside, in Mapes Alley, Southwark, and at the sign of the "Maremaid," in Lothbury, near Bartholomew Lane end, London.

Thus, whatever we may believe as to who first invented and used the pendulum, these two important practical facts seem to be true. It was Huygens who first brought the pendulum into prominence and it was his personal friend Fromanteel who introduced it into England.

The introduction of the pendulum. — The tremendous advantage of the pendulum as part of the controlling mechanism of a clock was at once apparent. The time-keeping accuracy was very much increased, in fact, so much increased that the pendulum was immediately applied to all clocks. And worse than this (from our point of view) many old clocks were rebuilt so as to use a pendulum. It

is this rebuilding of old clocks which makes it so hard to be sure of their original form or date. It will be remembered that there were four kinds of clocks in 1658 when the pendulum was introduced. There were: 1st, the large, sometimes intricate, weight-driven tower clocks; 2d, the large, intricate, weight-driven clocks which were placed inside cathedrals and public buildings; 3d, the small, brass, weight-driven bird cage or lantern clocks which were in common domestic use, particularly in England; 4th, the spring-driven, often intricate, table clocks which were invented in Germany and had their chief development there. To all of these the pendulum was at once applied. From now on during this period a *clock* will be considered a pendulum-controlled timekeeper. A balance-controlled timekeeper will be considered a watch or a clock-watch. It will be entirely immaterial whether the timekeeper is weight-driven or spring-driven. It is also interesting to note that in the French language the word for clock now began to be "pendule." The former word "horloge" began to become obsolete, at least for the domestic clock.

Changes in the controlling mechanism. — The introduction of the pendulum made necessary certain minor changes in the controlling mechanism of clocks. Up to this time all timekeepers, whether large turret clocks or the most diminutive watch, had exactly the same controlling mechanism. It was that pictured and described on page 83. It consisted of crown wheel, verge, and foliot balance. The crown wheel was now turned so that it rotated in a horizontal instead of a vertical plane. The verge became horizontal and the pendulum was attached to one end of the rod. It is thus evident that it was not a difficult task to reconstruct an old timekeeper so as to make it a pendulum clock. With the crown wheel and verge escapement the pendulum was usually light and not very long and its arc of swing was large. Fig. 106, which illustrates Huygens' clock, shows the new arrangement.

Other inventions and improvements were also made near the beginning of this period which were destined to

make the accuracy of clocks very much greater. In fact, some of them were almost as important as the introduction of the pendulum itself.

In 1676 the anchor escapement of the recoil type was invented by Robert Hooke. This is the same Robert Hooke who was probably busy with pendulums at the same time as Huygens. This escapement was introduced by William Clement in 1680 and is a great improvement over the verge and crown wheel. In fact this escapement is still used in most ordinary clocks at the present time. A more detailed treatment of it will be found on pages 181–187. This escapement, besides being much better, and causing greater accuracy in the running of a clock, also causes the pendulum to swing through a much smaller arc.

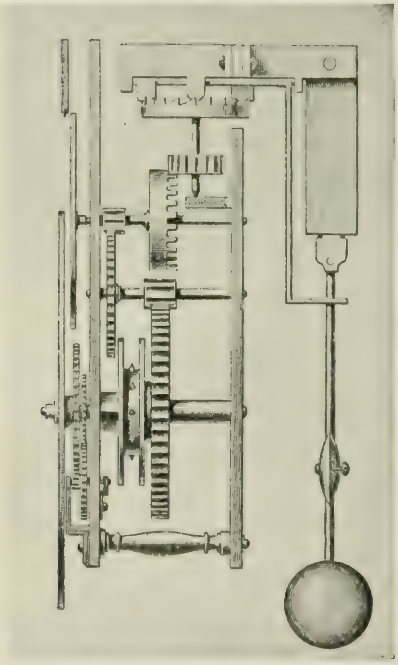


FIG. 106. HUYGENS' CLOCK.

The accuracy of timekeepers was so much improved by the introduction of the pendulum and this new escapement that between 1680 and 1690 the minute hand which had formerly been the exception now became the rule. Before this time, if a minute hand had been used, it ordinarily had a separate dial. From now on the under-the-dial mechanism just as used in clocks of today (see page 79) became common. A little later, when the accuracy warranted, the second hand was also added.

In 1715 the "dead-beat" form of the anchor escapement was invented by George Graham. "Honest George Graham,"

as he was often called, was born in 1673, died in 1751, and is buried in Westminster Abbey. Further details about his life will be given later. This dead-beat form differs but little from the recoil form. In the recoil anchor escapement, after a tooth of the escape wheel passes and one on the other side is caught by the horn of the anchor, the escape wheel is forced to move backwards slightly or recoil, as the pendulum moves on to the end of its swing. In the dead-beat form, the escape wheel is still or "dead" during this part of the swing. For ordinary clocks the recoil form is probably as good as the other, but for fine accurate clocks the dead-beat form is without doubt the best. One can easily tell by watching the motion of an escape wheel which kind a clock has. Do not expect to see, however, a large amount of backward motion or recoil on the part of any escape wheel in any modern clock. The difference in the two forms lies in the shape of the horns of the anchor and the teeth of the escape wheel.

As clocks became more accurate, the effect of changes of temperature on the rate of running became more apparent and from becoming apparent they became troublesome. The first invention to obviate the difficulty was the mercury compensation pendulum introduced by George Graham in 1721. It consisted of a vessel of mercury used instead of a pendulum bob. By making the quantity just right, it was possible to offset the expansion or contraction of the pendulum rod by that of the mercury. In 1726 the gridiron pendulum was invented by John Harrison. It may be that the honor of this too should go to George Graham instead of to Harrison. It consisted of nine bars of steel and brass so framed together that the temperature effect on one metal would be offset by that on the other.

The use of the vertical plates one at the front and one at the back for holding the clock movement also became common at this time. Formerly pillars had been more often used for holding the various parts of the mechanism.

Up to this time clocks were seldom constructed to run

more than one day (30 hours). Now clocks were often made to run a week, a month, or even a year.

It will be seen that from 1360 when the first unquestioned mechanical clock was produced by DeVick until 1658 there were practically no changes or improvements in clock mechanism. In less than one century following 1658 all these radical improvements were introduced and the clock became practically the clock of to-day. The last 150 years have seen only minor changes, constantly improved workmanship, and a steady increase in the timekeeping accuracy. All this applies of course only to pendulum-controlled clocks, which are the only ones treated in this chapter.

Clock cases. — We must now turn our attention from the mechanism of clocks to their cases. We shall find a great variety of cases during this period and the country will play a large part in determining how the clock mechanism was housed. Some kinds of cases will be much liked in one country and hardly used at all in others. Methods of ornamentation will be very different in different countries, for here "taste" and "style" played a large part. In general the style of ornamentation followed somewhat the style of furniture during the period, although designers and makers of furniture had extremely little to do with clocks. It will thus be necessary to consider the various countries separately.

English clocks. — In 1658 the clock used by the well-to-do householder who could own one was the brass bird-cage or lantern clock. This was the domestic clock of England at the time. There were of course some spring-driven table clocks which had been made in England or brought from Germany where this form originated and had its greatest development. They were, however, few in number and in the possession of the very rich. As soon as the pendulum was introduced it was applied at once to the bird-cage clock. Then some one conceived the happy idea of inclosing the pendulum and weights in a large wooden box or case which might stand upon the floor. This would

cover up the unsightly parts, keep dust out of the movement, and at the same time do away with the bracket. This bright idea was adopted at once, and behold! the first "grandfather" clocks came into existence. The exact date is uncertain; it was between 1660 and 1670.

Some claim that the hood clock, so called, marks the

FIG. 107. — AN EARLY HOOD CLOCK, BY JOHN KNIBB, OF OXFORD, DATE ABOUT 1690.

(From Cescinsky and Webster, *English Domestic Clocks*.)

transition from the bird-cage to the grandfather clock. Such a clock is illustrated in Fig. 107. It is a 30-hour alarm clock made by John Knibb of Oxford. The case is of oak, veneered with ebony. The dimensions are 20 inches by $9\frac{1}{2}$ inches by $6\frac{1}{4}$ inches. The dial is $5\frac{1}{4}$ inches square and there is but one hand. The date is about 1690. Those who make this claim think that the brass bird-cage clock

was first covered over with a wooden hood and later came the addition of the rest of the case. However this may be, the total transition took a very short time and the hood clock was never popular.

The first cases for grandfather clocks were of painted pine or oak, but the desire for ornamentation led at once to veneering with walnut, ebony, and other woods, and also to the use of carving, panels, and inlay work. Elaborate inlay work in patterns is called marqueterie or marquetry. The Dutch probably excelled in inlaying at this time, so that many of the first marquetry cases may have been imported from Holland. Later, about 1710, lacquer work made its appearance, and here again the Dutch may have excelled at the start. Finally (after 1750) mahogany became and has continued to be the favored wood. In Figs. 108 to 115 inclusive are pictured eight English grandfather clocks. Some of them are by well-known makers and they were chosen to illustrate type forms. They illustrate veneering, paneling, inlay work, marquetry, lacquer work, and the use of mahogany.

The first (Fig. 108) is in the South Kensington Museum in London and was made by Henry Simcock, of Daintree. The case is of pine painted black and the date is 1714. It is 6 feet 10 inches high, 1 foot 9 inches wide, and 11¼ inches deep. It has corkscrew pillars and but one hand.

The second (Fig. 109) is also in the South Kensington Museum. The case is decorated with marquetry of various woods. It has corkscrew pillars, two hands, and is a late seventeenth-century or early eighteenth-century production.

The third (Fig. 110) is in the possession of the Rev. Dr. Cranage of Cambridge. It has a handsome marquetry case, two hands, and black corkscrew pillars.

The fourth (Fig. 111) is in the Metropolitan Museum of Art in New York City. It is in a plain ebony case and made by the famous Thomas Tompion (1639–1713). Although an early eighteenth-century clock, it already has the semicircle at the top of the dial.

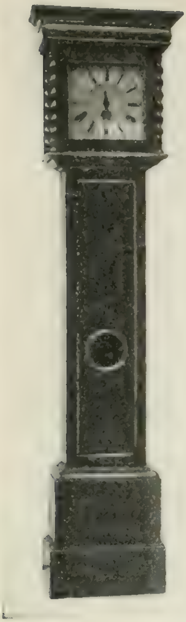


FIG. 108. — AN ENGLISH GRANDFATHER CLOCK, BY HENRY SIMCOCK, OF DAINTREE, DATE 1714.

FIG. 109. — AN ENGLISH GRANDFATHER CLOCK IN A MARQUETRY CASE.

FIG. 110. — AN ENGLISH GRANDFATHER CLOCK, DATE ABOUT 1700.

The fifth (Fig. 112) is in the South Kensington Museum. It was made by Daniel Torin, London, in 1761, and the case is in green and gold lacquer. It is 7 feet 7 inches high, 1 foot $7\frac{5}{8}$ inches wide, and $9\frac{5}{8}$ inches deep.

The sixth (Fig. 113) is in the Metropolitan Museum of Art. The case is of mahogany, inlaid with satin wood. It was made by John Whitehurst (1713–1786) of Derby.

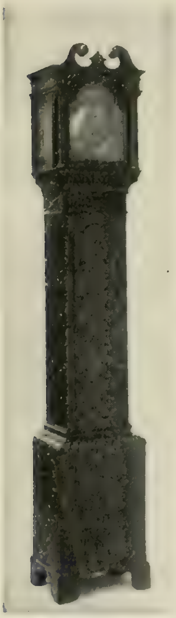


FIG. 111. — AN ENGLISH GRANDFATHER CLOCK, BY THOMAS TOMPION.

FIG. 112. — AN ENGLISH GRANDFATHER CLOCK, BY DANIEL TORIN.

FIG. 113. — A GRANDFATHER CLOCK, BY JOHN WHITEHURST, OF DERBY.

The seventh (Fig. 114) is in the South Kensington Museum. The case is of carved mahogany and it is signed "Barker, Wigan." It dates from about 1780. It is 7 feet $9\frac{1}{4}$ inches high, 1 foot $9\frac{1}{2}$ inches wide, and $10\frac{1}{4}$ inches deep.

The eighth (Fig. 115) is also in the same museum. The case is of mahogany, inlaid with satin wood. The dial is painted. It was made by Edward Shepley of Manchester

FIG. 114.—A CLOCK IN A MAHOGANY CASE, BY BARKER, OF WIGAN.

FIG. 115.—A CLOCK IN A MAHOGANY CASE WITH A PAINTED DIAL, BY EDWARD SHEPLEY, OF MANCHESTER.

and dates from about 1790. It is 7 feet 6¾ inches high, 2 feet 2 inches wide, and 11 inches deep.

At first the hood or top of the case was rectangular in shape; then spires and ornaments were added; and finally the broken arch became common. In the early clocks twisted or corkscrew pillars were much used. The dials were at first about ten inches square and later became a little larger. They were of brass and often decorated with engraving. Later the semicircle at the top was added. This contained just a picture, or the seconds dial, or the name of the maker, or the moon phases, or the "strike-silent" dial. Much attention was given to the brasswork corners on the face just outside the hour circle, the spandrels, as they were called. These were of brass, pierced, and well made. The cherub's head was a much-liked design. Very late in the period, enameled dials were used or for a few clocks even painted dials. So well marked are these transitions that the expert who studies the size and form of the hands, the size and workmanship on the dial, the spandrel corners, the form and decoration of the hood, and the material of the case, can form a fairly close estimate as to the age of the clock. By again noticing the eight illustrations (Figs. 108–115) and considering the date of each clock, many of these points will become clear. It must always be remembered of course that an old style always persists long after a new style has appeared. This makes one's estimate of age too great, never too small. Thus, as an example, take the clock illustrated in Fig. 110. The case has marquetry inlay in panels. The dial is square and the spandrels are cherub heads. The hood has black corkscrew pillars. But the minute hand is present. This clock might be as old as 1680; 1700 would perhaps be the best estimate; one would hardly expect it to date later than 1720.

But grandfather clocks were not the only form of ordinary domestic clocks made in England during this period. The table clock had a parallel development. This might just as well be called a bracket clock, or a mantel clock, since being spring-driven and portable it might be placed

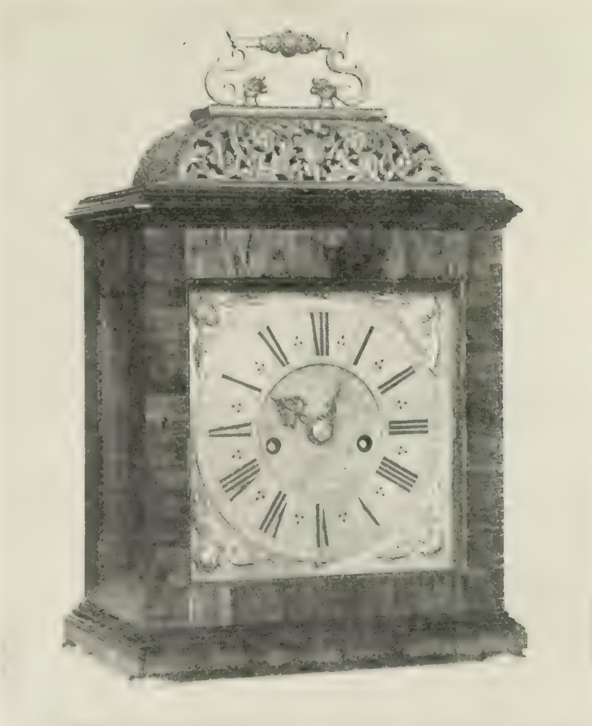


FIG. 116.—AN ENGLISH TABLE CLOCK, BY JOHN FROMANTEEL.

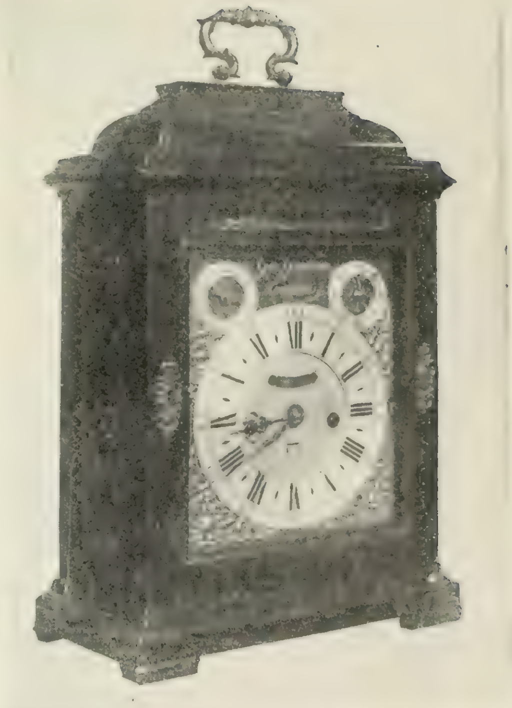


FIG. 117.—AN ENGLISH TABLE CLOCK, BY GEORGE GRAHAM.

in any of these positions. Three splendid examples are illustrated in Figs. 116–118. It will be noticed that in general they follow the styles in grandfather clocks.

The first (Fig. 116) is in the South Kensington Museum, lent by Lieut.-Colonel G. B. Croft Lyons. The case is of walnut. It was made by the famous John Fromanteel of

FIG. 118. — AN ENGLISH TABLE CLOCK, BY JAMES CHATER.

FIG. 119. — AN INN CLOCK. (From CESCINSKY AND WEBSTER, *English Domestic Clocks.*)

"Ye Mermaid," Lothbury, London, and thus dates from the last part of the seventeenth century.

The second (Fig. 117) is by George Graham. The photograph was furnished by Mr. Malcolm Webster. It is an eight-day striking and repeating clock in an oak case veneered with ebony. It is 16 inches high (not including

handle), $9\frac{1}{2}$ inches wide, and $5\frac{1}{2}$ inches deep. It dates from about 1720. The two small dials are an "up-and-down" and a "strike-silent" dial, respectively.

The third (Fig. 118) is in a red lacquer case. The photograph was also furnished by Mr. Malcolm Webster. It was made by James Chater of London, who joined the C. C. in 1727. It is a musical clock, playing five different tunes.

Just before the end of this period the Inn clock or "Act of Parliament" clock made its appearance. It is often said that Pitt's tax of five shillings on each clock per annum, which was levied in 1797, caused domestic clocks to fall out of use and the inn clocks to appear immediately. It is more likely simply a form of clock much used in inns at this time. These clocks were usually plain and hung on the wall. Sometimes they were lacquered and even decorated in gold. There was usually no glass covering over the dial. One of these is illustrated in Fig. 119. This one is in a lacquer case and was made by Matthew Hill of Devonshire Street. It dates from the last of the eighteenth century.

French clocks. — In France the introduction of the pendulum also produced the grandfather clock, but its outward appearance, due to the prevailing fashion in decoration, was quite different. Ormolu mounts and Boulle work were the two common forms of ornamentation. Ormolu (from the French, "or moulu," ground gold) mounts consist of brass ornaments, usually well gilt, which are fastened to the case. Boulle work is named after Charles André Boulle (1642–1732), who was a master inlayer and decorator. It is an inlay of metal, usually white metal or brass, and tortoise shell. The shell was often colored or stained with various colors. Boulle work in English is sometimes spoken of as Buhl.

Two of these clocks are illustrated in Figs. 120 and 121. They are both in the Conservatoire des Arts et Métiers at Paris. The first (Fig. 120) is by Lepaute, who was born in 1709 and was later appointed "clockmaker to the king." The second (Fig. 121) is a striking clock of about the same

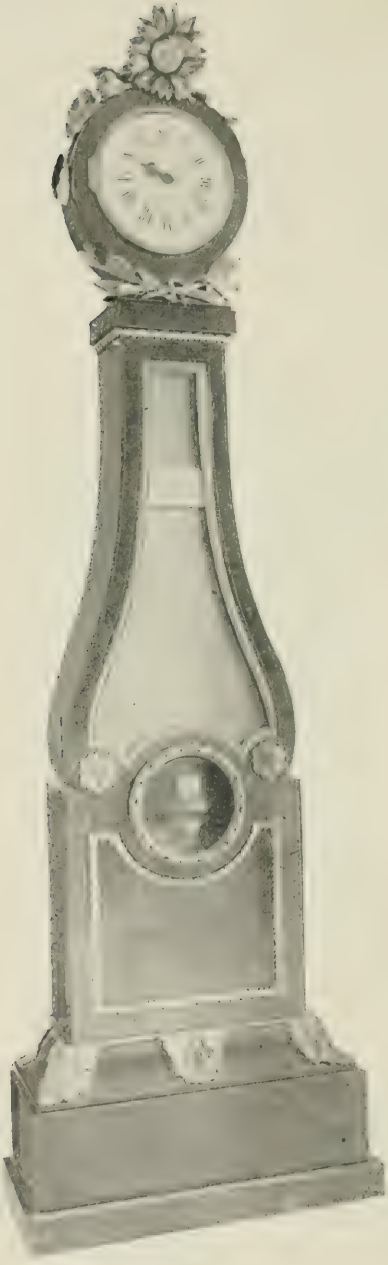


FIG. 120. — A FRENCH GRANDFATHER CLOCK, BY LEPAUTE.

FIG. 121 — A FRENCH GRANDFATHER CLOCK IN THE STYLE OF LOUIS XV.

date. They both belong to the Louis XV period. Their outstanding characteristics as compared with English grandfather clocks are the ormolu mounts, the bulging center of the case, and the lack of straight lines in general. It must not be supposed, however, that all French grandfather clocks are as elaborate as those illustrated. In private families, particularly in small cities and villages, one often finds grandfather clocks which are claimed to be much more than a century old. They are usually in plain wooden cases and sometimes they have been painted. They practically always have, however, the typical bulge in the center. Occasionally one finds a very tall straight case. The height is often about nine feet and the wood is dark and sometimes carved. One suspects here foreign influence, particularly that of the Black Forest region.

The true pedestal clock was also a favorite in France. In fact there are really three forms of the pedestal clock. In the first place the pedestal and clock may be so intimately joined together that they seem one piece and resemble quite a little the grandfather clock. In the second place the clock may simply stand on a pedestal, but the pedestal is necessary and these clocks are sometimes called true pedestal clocks. The pedestal is necessary because the pendulum is so long that it extends into the pedestal and, if the clock is weight-driven, the weights do the same. Thirdly the clock may simply stand on a pedestal. The pedestal is unnecessary and these clocks might be used as table, bracket, or mantel clocks. In Figs. 122 to 125 four of these pedestal clocks are illustrated. The first and second belong to the first category, the next one is a true pedestal clock, and for the last one the pedestal is unnecessary.

The first one (Fig. 122) is in the Louvre in Paris and is the work of Carlin et Gouthière. The second (Fig. 123) is in the Palace of Fontainebleau. The third (Fig. 124) is in the Wallace collection, at Hertford House, London. It is by Mynuel of Paris, with a case and pedestal by Boulle. It was purchased in 1863 for £6000. The fourth (Fig. 125) is in the Art Museum at Boston, loaned by Mrs. Albert

FIG. 122. — A FRENCH PEDESTAL CLOCK IN THE LOUVRE.

FIG. 123. — A FRENCH PEDESTAL CLOCK IN THE PALACE OF FONTAINEBLEAU.

FIG. 124.—A PEDESTAL CLOCK, BY MYNUEL AND BOULLE.
(Wallace Collection, London.)

FIG. 125.—A FRENCH PEDESTAL CLOCK, BY BALTHAZAR, OF PARIS.

FIG. 126. — A BRACKET CLOCK, BY THIOUT L'AINÉ
(Garde Meuble, Paris.)

FIG. 127. — A BRACKET CLOCK, BY MYNUEL.
(Louvre, Paris.)

Felix Schmitt. The works are by Balthazar of Paris and it dates from about 1770. The clock case is of tortoise shell inlaid with brass and the pedestal is of ebony and brass inlay. The total height is 1.38 meters.

Bracket or table clocks were also in high favor during this period and seem to have appeared, as in England, almost simultaneously with the grandfather and pedestal clock. Three of these are illustrated in Figs. 126 to 128. The first (Fig. 126) is by Thiout l'Aîné and is in the "Garde Meuble" at Paris. It dates from the time of Louis XIV. The second (Fig. 127) is in the Louvre at Paris and is by Mynuel. The third (Fig. 128) is in the Wallace collection at Hertford House. It is by Thuret of Paris.

The Cartel clock (perhaps from the Italian Cartela, a bracket) was also used. It was round or oval in form and fastened to the wall. The case was of wood, lead, zinc, or brass. Thickly gilt brass was probably the most common form. These cartel clocks were introduced during the reign of Louis XIV (1643-1715) and were in especial favor during the reign of Louis XV (1715-1774). One of them is illustrated in Fig. 129. It is in the Musée Carnavalet at Paris and was made by Bunon. It dates from about 1770.

The mantel clock which is so much loved by the French and which is still made in large numbers, also made its appearance during this period. They were very rare before the time of Louis XV and it is the reign of Louis XVI (1774-1793) which saw their great development. One of them from the time of Louis XVI is shown in Fig. 130. It is in the "Garde Meuble" at Paris, the work of Cachard, the successor of Ch. Le Roy.

Dutch clocks. — In the Netherlands the bracket or hood clock was the great favorite during this period. The bracket clock probably appeared in the Netherlands as early as the bird-cage or lantern clock did in England. At first it had but one hand and the controlling mechanism consisted of foliot balance, verge, and crown wheel. Later the pendulum was used and two hands became the rule. These clocks were always fastened to the wall and were

FIG. 128. A BRACKET CLOCK, BY THURET, OF PARIS.
(Wallace Collection, Hertford House, London.)

FIG. 129. — A CARTEL CLOCK, BY BUNON.
(Musée Carnavalet, Paris.)

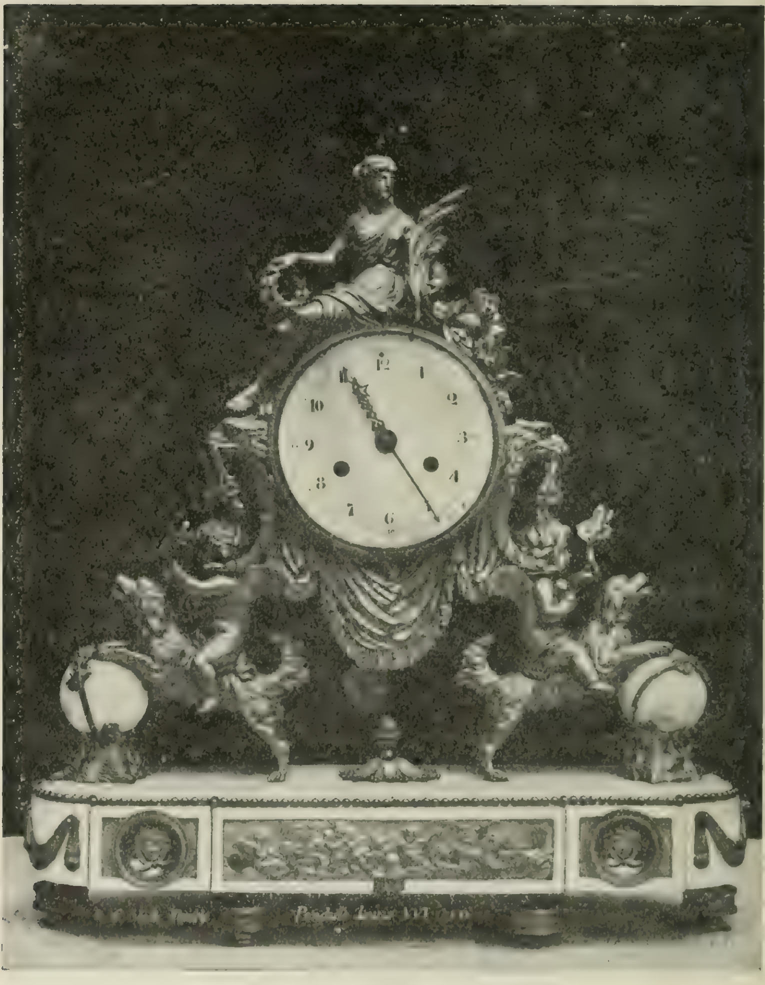


FIG. 130. A MANTEL CLOCK FROM THE TIME OF LOUIS XVI.
(Garde Meuble, Paris.)

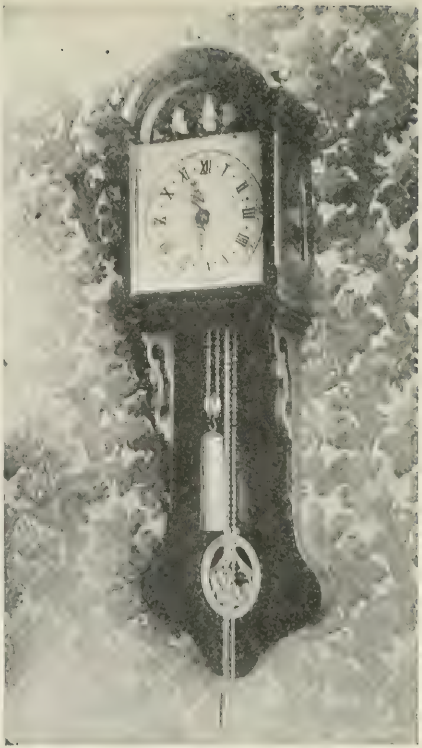


FIG. 131. – A FRIESLAND HOOD CLOCK.

FIG. 132. – A DUTCH HOOD CLOCK.

thus bracket or hood clocks. They were never placed on a pedestal, table, or mantel. These clocks are noted for individuality, quaintness, and sometimes almost grotesqueness. There are still many of them in use in the country districts of Holland. A visitor to the Island of Marken

FIG. 133. — A DUTCH HOOD CLOCK IN ESSEX INSTITUTE, SALEM, MASS.

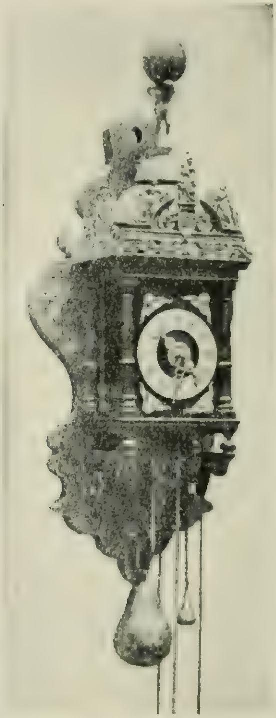


FIG. 134. — A ZAANDAM CLOCK.

will see a great many. Four of these are illustrated in Figs. 131 to 134. The first two belong to Mr. William Moulton, who has the finest collection of these clocks in America and perhaps in the world. The pictures were furnished by Miss Mary H. Northend, of Salem, Mass., from her immense collection. The third is in Essex Institute,

Salem, Mass. The fourth belongs to a dealer in antique clocks, H. Brokke, Vijzelstraat 112, Amsterdam, Holland.

There are in reality three different kinds of hood clocks. The clock illustrated in Fig. 131 is usually called a Friesland clock, while the one illustrated in Fig. 134 is a Zaandam clock. Unfortunately in America the names Friesland, Zaandam, and Dutch are used almost interchangeably.

FIG. 135. — A DUTCH GRANDFATHER CLOCK IN THE MUSEUM BOYMANS, AT ROTTERDAM.

The grandfather clock was also quite common, but it does not seem to have been the great favorite. It was similar to the English grandfather, but there are two distinguishing features — the form of the base and the ornament on the center of the door. The base swells out and has curved lines instead of straight. It is sometimes spoken of as the fiddle or kettle base. Sometimes there are projections on the two front corners of the base. Two of these Dutch grandfather clocks are illustrated in Figs. 135 and 136. The two distinguishing features are easily noticeable. The first one (Fig. 135) is in the Museum Boymans at Rotterdam. It was made by Lourens Eichelar and dates from about 1760. The case is of oak

veneered with walnut. It has an eight-day brass movement with chime barrel and the four ships above move with the pendulum. The second (Fig. 136) is in the possession of H. Brokke of Amsterdam.

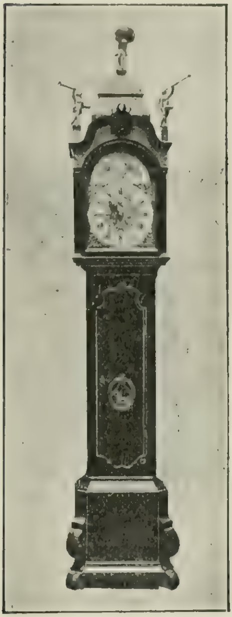


FIG. 136. — A DUTCH GRANDFATHER CLOCK.

Many of the Dutch grandfather clocks have calendar and moon-phase attachments and sometimes there is a scene with moving figures. A favorite one consists of ships rocking on the waves with the motion of the pendulum.

Other countries. — In Italy the grandfather clock was more like the French than the English form, although the bulge in the center of the case is not so common. There are very, very few to be found in museums.

In Germany the grandfather clocks were made in imitation of either the French or the English style. Sometimes the case was very long and straight, made of dark wood, and ornamented with wood carving. The hood clock was also popular and the cuckoo clock which was first made by Anton Ketterer in Schönwald in the Black Forest in 1730 may be considered to belong to this class. The table clock, which up to 1658 had seen its greatest development in Germany, continued to be a favorite. It was sometimes made in imitation of the French style with a case ornamented with ormolu and Boulle work.

Clocks as antiques. — Practically all of the different kinds of clocks which are so much sought after as antiques originated, as we have seen, during this period. The two kinds which antedate the period are the English bird-cage or lantern clock and the table clock, which originated in Germany and was very soon made in all countries. There are two questions which are often asked, (1) where may

antiques be procured and (2) what is their value. The self-evident answer to the first question is at the shops of the dealers in antiques. Nearly every dealer in antiques includes clocks (and perhaps watches) in his line and thus one is likely to find at least a few antique clocks. Some dealers specialize in them and then one is sure to find more.

In London Percy Webster and his son Malcolm R. Webster at 37 Great Portland St., London, W. 1, specialize particularly in clocks, watches, and antique jewelry. Their stock of antique clocks is immense and runs up into the hundreds of examples. Here one can always find old clocks by well-known makers and in all kinds of cases. These gentlemen are experts in their line and their integrity and reliability are unquestioned. Jump & Sons, 93 Mount Street, London, W. 1., also specialize in old clocks.

Dutch clocks can always be procured in Amsterdam or Rotterdam. H. Brokke, Vijzelstaat 112, Amsterdam, Holland, carries a large stock of very fine Dutch hood and grandfather clocks. An illustrated catalogue may be procured from him. There are also several other dealers in antiques in Nieuwe Spiegelstraat, Amsterdam, who carry fairly large stocks of antique clocks. In Rotterdam A. M. Lucas, Witte De Withstraat 61 B, also specializes in antique Dutch clocks.

In France good grandfather or pedestal clocks are hard to find. Bracket or table clocks of the time of Louis XIV, Louis XV, or Louis XVI are to be found at the shops of nearly all dealers in antiques.

It is practically impossible to state the cost of an antique clock. It depends entirely upon the kind, age, maker, and condition. A grandfather clock by a known maker, in good condition, and a genuine antique will cost from $200 to $800 or even higher. A Dutch hood clock costs from $15 to $90. A French bracket or table clock, Louis XV style, costs from $100 to $300. But there are many clocks which have sold for more than $10,000 and it is doubtful if the upper limit to the price which has ever been paid for an antique domestic clock could be put under $50,000.

CHAPTER XI

THE HISTORY AND CONSTRUCTION OF THE INDIVIDUAL PARTS OF CLOCKS

In this chapter the history, development, and present-day structure of the various individual parts which make up clock mechanism will be considered in detail. If Chapter V on the construction of the simplest possible clock has been forgotten, it would be well to read it again as an introduction to this chapter. It will be once more assumed that the clock is simply a timepiece in the primitive sense of that term; that is, that there are no attachments of any kind. The additional parts which are necessary if a clock has striking, chiming, alarm, calendar, moon-phase, equation of time, or repeater attachments will be considered in the next chapter. These three chapters (V, XI, and XII) thus constitute a short treatise on clock mechanism which could be read almost independently of the rest of the book. In taking up the various parts, they will be grouped under the driving, transmitting, controlling, and indicating mechanism just as before.

The driving mechanism consists of either a weight or a tightly coiled steel spring. Historically the weight was used a good four centuries before the spring. The very first clocks were weight-driven, while the mainspring was introduced by Peter Henlein of Nürnberg in 1500.

If a weight is used it must be heavy enough to keep the clock running. There is friction to be overcome and, as the oil thickens and dirt collects around the pivots, the friction increases. Sometimes a clock which has not been recently cleaned stops on account of it. A heavier weight might have driven the clock longer, but it would not have been good for the clock. The moral is that the weight should be ample, but too much overweight is not good for

the clock. The amount of fall must be sufficient to allow the clock to run the proper length of time. Usually there is at least a 10 per cent and generally a 25 per cent leeway. The weight is attached to a cord which is wrapped around the drum. There are several ways of doing this. The weight may hang directly from the drum, but this is not usual now. There may be a pulley at the top of the weight. Then one end of the cord is fastened to the frame of the clock and the cord often passing around the pulley is wrapped around the drum. Sometimes the cord passes over a pulley at the top of the clock case. This is a very common way in old clocks. It is not always a cord that is used. Sometimes its place is taken by catgut or a flexible wire. Sometimes the weight is fastened to a flat chain which passes over a wheel with projecting points to keep it from slipping. This is a common method in many grandfather clocks. Most of these methods were illustrated in Fig. 43. The drum is connected to the main driving wheel by means of a ratchet and click. This is necessary in order that the clock may be wound up again when the weight has run down. This is accomplished in the case of the flat chain by simply pulling the free end of the chain. In the other methods the weight is wound up by means of a key in which there is a square hole which fits over the squared end of the arbor, to which the drum is rigidly fastened, but upon which the main driving wheel rides free. Weights are made of either iron or lead and are often encased in brass to add to their appearance. The individual parts of the driving mechanism are thus the weight, cord, drum, ratchet, click, click spring to keep the click against the ratchet, main driving wheel and the arbor.

The mainspring is probably more used at present to drive clocks than the weight. The truth of this is at once apparent when one considers the immense number of small alarm clocks at present which are all spring-driven. There are two ways of attaching the spring. In some good clocks it is placed in a going barrel just as in a watch (see page 103). This is true of the clock movement pictured in

Fig. 152. Usually (always in cheap clocks) one end of the spring is fastened to the frame of the clock and the other is fastened to the arbor. The spring is wound up by means of a key as before or by means of what is practically a key, which is fastened to the end of the arbor. A good spring will not be too strong or too weak; it will be smooth and well polished and not left long enough without cleaning to be gummy; it will unwind evenly and not be kinked or buckled. The making and tempering of the springs used in modern clocks and watches are an interesting part of their manufacture. The great objection to the use of a spring in a clock which is to keep accurate time is that the pull is much greater when just wound up than when partially run down, and this affects the rate of running of the clock. This is partially overcome by using a long spring. So great was this difficulty with the early springs that the fusee was invented by Jacob Zech in 1525 to equalize its pull. The fusee has been fully described on page 126. When first invented it had a very general application. At present, fusees are found in chronometers, a few watches, and a very few clocks, all of them being expensive and good ones. All accurate clocks used for astronomical purposes, or where correct time is essential, are weight-driven.

There are two attachments which are sometimes added to the driving mechanism of good clocks. These are maintaining power and stop work.

The purpose of maintaining power is to keep the clock running while it is being wound. When the power is taken off in winding, the clock movement usually stops while the pendulum keeps on swinging. This of course would not do in a clock which is to keep accurate time. Historically the first form was the endless chain invented by Huygens, but that has gone entirely out of use. There are also a couple of other forms which have never come into general use. The two used at present are "the bolt and shutter" and the "double ratchet" forms. Of these the first has almost gone out of use while the second is the one generally employed.

The bolt and shutter came into use sometime before

1700 and was often applied to the grandfather and table clocks of that period. It is still occasionally met with in tower clocks. It consisted of a shutter which covered the winding hole. Thus to wind the clock a lever had to be raised to uncover the hole. The raising of the lever inserted a spring bolt in the cogs of the main driving wheel or one of the wheels of the train. The weight of the lever would then run the clock until the bolt ran out of gear and the shutter had covered the hole again. The only purpose of the shutter was to make it impossible to forget to raise the lever before beginning the winding.

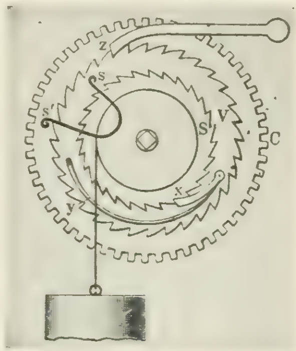


FIG. 137. — HARRISON'S MAINTAINING POWER.

The double ratchet form of maintaining power, invented by Harrison (1693–1776), is much better and is the form always used now when maintaining power is applied to a clock. It is pictured in Fig. 137 and consists simply of a second ratchet and click connected to the main driving wheel by means of a spring. While the clock is being wound it is click Z that holds and the clock is driven by the spring SS'. Ordinarily it is click X that holds and the weight drives the clock. There is of course no need of maintaining power in the case of a spring-driven timekeeper with a going barrel. Here the tension is a little greater on the movement when the timekeeper is being wound.

Stop work is applied to a clock to prevent it from being wound too tight, and also at times to make use of a certain middle portion of a spring which is too long and powerful.

There are several forms of stop work which have been invented, but only two have any general application now. One of these is used on chronometers and will be described in that chapter. The other is the form used on practically all clocks and watches which have stop work. It is called

the star wheel, the Maltese cross, or the Geneva stop. The various names indicate its origin and appearance. It is illustrated in Fig. 138 and consists of a wheel with one tooth or finger *A* which is attached to the barrel arbor. The star wheel *S* which turns on a stud has five or more tooth-like projections. It will be noticed that the one at *B* is different from the rest in that it is longer or convex instead of concave. In the figure the stop has come to the end of its motion. When the clock or watch is wound up the finger wheel will move in the direction of the arrow and for each revolution will pull the star wheel forward one tooth. After making five revolutions (nearly) the stop will again

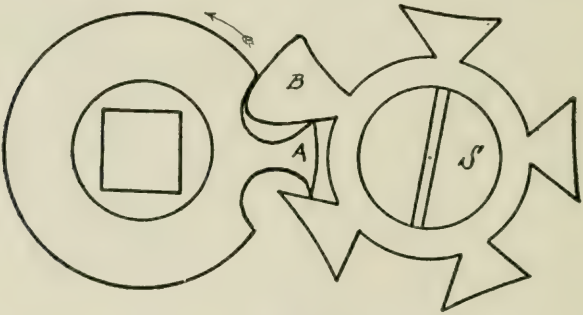


FIG. 138. — THE GENEVA STOP.

operate. Thus the spring or weight can be wound up and can run down just five complete revolutions of the barrel arbor and no more. This is the form always used on watches where the going barrel turns just three times in a day and five times before it runs down. In a clock if more revolutions are desired between up and down there must be more teeth on the star wheel. Stop work can be readily seen on the clock movement pictured in Fig. 151.

As has been said, other forms of stop work have been invented. Two of these will be described chiefly on account of their ingenuity. They are probably not used on any timekeeper made at present. The first consists of multiple concentric discs and its action is evident from

Fig. 139. As illustrated, the stop has operated and the arbor is at the end of its motion. When the timekeeper is wound up, disc *A*, which is firmly attached to the arbor, turns in the direction of the arrow. After one turn the projection comes in contact with the pin *a* and the disc *B*, which is free, is carried along. At the end of the second turn the projection on *B* comes in contact with *b* and the third disc is carried along. This continues until finally the projection on *M* comes in contact with the fixed stop *m*. It is evident that the arbor can make as many turns between up and down as there are discs.

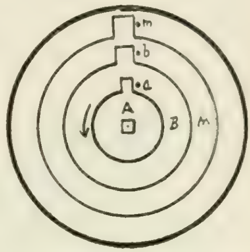


FIG. 139. — A MULTIPLE DISC WINDING STOP.

Another form of stop work is illustrated diagrammatically in Fig. 140. The smaller wheel is attached to the arbor and has, say, 40 teeth. The larger wheel turns on a stud and has 50 teeth. Different numbers could be chosen. On each wheel there is a projection. As illustrated, the arbor is at the end of its motion and the stop has operated. When the timekeeper is wound the smaller wheel moves in the direction of the arrow. At the end of one turn the stop does not operate, as the projection on the larger wheel is at *M*. At the end of about five turns in this case the projections come together and the stop operates. In general the number of turns equals the number of teeth on the larger wheel divided by the difference in the number of teeth on the larger and smaller wheels.

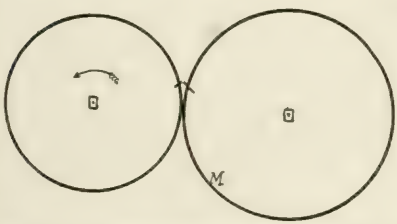


FIG. 140. — A TWO-WHEEL WINDING STOP.

The transmitting mechanism consists of a series of cogged wheels working one in another. It extends from the main driving wheel of the driving mechanism to the pinion

on the escape wheel arbor which is part of the controlling mechanism. The driving wheels are called wheels and have teeth. The driven wheels, which are smaller and wider, are called pinions, and have leaves. One wheel and one pinion are always mounted on an axle or arbor which ends in pivots which run in holes in the plates which hold the mechanism (see Figs. 47 and 48). The wheels are of brass, but the pinions and arbors are of steel. Sometimes in small clocks and in good ones the pivot holes are jeweled, as in a watch. There may be one, two, three, or even five, or six arbors in the transmitting mechanism. The number depends somewhat upon the maker, but mostly upon the length of time the clock is to run. The transmitting mechanism is often spoken of as the time train.

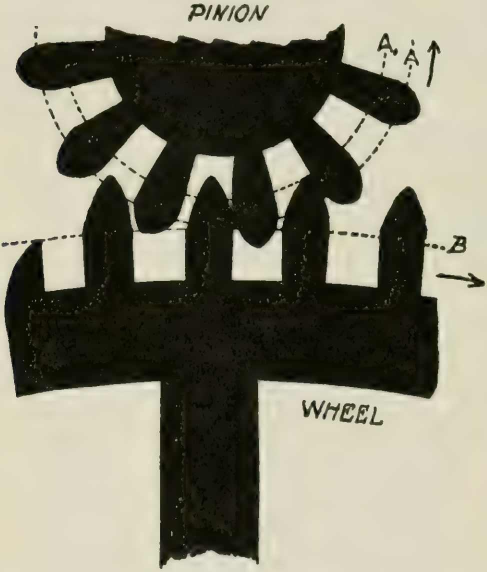


FIG. 141.—THE SHAPE OF THE TEETH AND LEAVES OF A WHEEL AND PINION.

The one new and important thing to bring out here is the shape of the teeth and leaves of the wheels and pinions. A general idea of the arrangement of things can be gained from Fig. 141, which shows a portion of a wheel of 120 teeth and a pinion of 12 leaves. The two circles *A* and *B* are known as the pitch circles. The portion of the leaf or tooth which extends beyond these circles is known as the addendum. The portion below the pitch circles is called the root. The sides of the leaves as far as the pitch circle *A* are straight radial lines. The addenda are semicircles and

extend about one half as far beyond the pitch circle as the width of the leaves. The ratio of the leaf to the space between is about 4 to 6. The teeth of the wheel also have straight radial sides as far as the pitch circle *B*. The addenda are about $1\frac{1}{8}$ times as long as the width of the teeth and their shape is epicycloidal. The first point of contact of a tooth and a leaf is where the pitch circles *A* and *B* are tangent to each other on the line connecting the centers of the wheel and pinion. The last point of contact is on the circle A. Now, of course, there is a reason for all these things and it will be given next. Those who dislike technical details may simply look over or even overlook the next page.

The general problem is this. Given the distance between centers and the ratio of the wheel and pinion to each other, to devise a wheel and pinion which shall be most satisfactory and have the least friction and wear. To make it a definite numerical example: suppose the distance between centers is 1.65 inches and that the pinion is to make 10 revolutions to one of the wheel. Then the wheel must have $\frac{10}{11}$ and the pinion $\frac{1}{11}$ of the distance between centers. That means the pitch circle of the wheel will have a radius of one and a half inches and that of the pinion 0.15 inch. As a tooth of the wheel meets a leaf of the pinion, they roll or slide upon each other, engaging deeper and deeper until the line of centers is passed. Then they draw apart until the tooth leaves the leaf. Now the friction and wear due to engaging is much greater than the disengaging friction. Thus the tooth should not meet the leaf until at or beyond the line of centers. It can be shown mathematically that this is impossible unless the pinion has at least 10 leaves or more. In practice pinions have from 7 to 16 leaves. The lower numbers are used in small cheap clocks. Suppose then we fix upon 12 as the number of leaves for the pinion. The wheel in the given problem must then have 120 teeth. The wheel and pinion can now be laid out. The ratio of 6 to 4 for space and leaf in the pinion and an even ratio for tooth and space in the wheel

are dictated by practical considerations of strength and clearance. In fact it is a little different with different makers and with different sizes of wheels and pinions. The addenda to the pinion leaves could be anything, as they are not used. The semicircle is the most convenient to make, best looking, and serviceable. The shape of the addenda of the teeth must be such that the face will always be tangent to the straight radial side of the leaf. This is the same thing as saying that there must be only rolling friction and no sliding friction. It can be shown mathematically that to fulfill this condition the face must have the shape of an epicycloid. The lengths of the addenda are dictated by practical considerations in order to avoid any slipping due to jar or wear.

There is another entirely different kind of pinion which is in very general use. It is called the lantern pinion and it was illustrated in Fig. 44. It consists of circular wires arranged in the form of a drum. It has several distinct advantages. It is cheaper to make, it will stand more abuse, it is less liable to stoppage due to dirt, and there is less friction when the number of wires is the same as the number of leaves. It is the form almost always used in cheap alarm clocks and sometimes in old-fashioned clocks with wooden wheels.

The controlling mechanism is the most vital part of a clock and it is thus natural that many different forms have been devised. Historically the first consisted of foliot balance, verge, and crown wheel. This form had undisputed sway from the time of the first mechanical clock until 1658, when the pendulum was introduced into clock mechanism. It was fully described and illustrated on page 83 and has now gone entirely out of use.

From 1658 to the present day probably nearly three hundred different forms of escapement have been devised, but of these less than ten have stood the test and had an extended use. Seven of them will be described in more or less detail in this book. A few others will be mentioned here and there in passing.

The chronometer escapement is used in all chronometers and a few watches; it will be described in the chapter on chronometers. The Denison gravity escapement is used in most tower clocks and a few accurate clocks; it will be described in the chapter on tower clocks. Either the lever, the cylinder, or the duplex escapement is used in practically all watches, and in all clocks built like watches; that is in all spring-driven, balance-controlled clocks; these three will be described in the chapter on watch mechanism.

The anchor escapement of either the recoil or the dead-beat form is used in practically all pendulum clocks; these two will be considered in this chapter. The word escapement is sometimes used as almost synonymous with the controlling mechanism. This is not quite correct. The escapement consists of those parts directly concerned in allowing the teeth to escape. Thus the anchor and escape wheel make up the escapement but the pendulum is also a part, and an important one, of the controlling mechanism. The escapement is thus only a part of the controlling mechanism.

If an anchor escapement of the recoil form is used, then the controlling mechanism consists of pendulum, anchor, escape wheel, and perhaps a rod to connect the pendulum with the anchor and called the crutch. Each of these parts must be considered in detail. The recoil anchor escapement was invented by Robert Hooke in 1676 and introduced into clock mechanism by William Clement in 1680 and is now used in perhaps 90 per cent of all pendulum clocks. It can be cheaply made; it is but little affected by changes in the driving power, and the lubrication also makes but little difference; it will give fair results under the worst possible conditions. For these reasons some would even consider it better than the dead-beat form. This, however, is a mistake. In a well-made, accurate clock the dead-beat form will give better results.

A simple recoil anchor escapement is illustrated in Fig. 142. It consists of the escape wheel A and the anchor B. The two ends of the anchor at C_1 and C_2 are called the horns of the anchor or the pallets. The pendulum may be at-

tached directly to the anchor, but this is unusual. Ordinarily there is a rod, called the crutch, which is firmly attached to the anchor and also connects with the pendulum. One method of connecting the two was illustrated in Fig. 46. The last wheel in the time train drives the pinion on the escape wheel arbor and thus tries to turn the escape wheel in the direction of the arrow. As the pendulum swings to the right and with it the anchor, a tooth escapes at C_2, but the escape wheel is not free to turn far as a tooth is caught on the pallet at C_1. As the pendulum continues its excursion to the right the escape wheel is forced to move backward or recoil slightly and this gives the name to the escapement. The pendulum has now come to rest and begins its swing to the left. A tooth at C_1 is soon released but another tooth is again caught on the pallet at C_2, and the further motion of the escape wheel stopped. As the pendulum swings backward and forward one tooth passes the pallets for each full swing of the pendulum. Since there is air resistance and friction, some power must be supplied to the pendulum to keep it swinging. This comes from the escape wheel, for as each tooth escapes it gives to the pallets a push which is communicated to the pendulum and keeps it swinging.

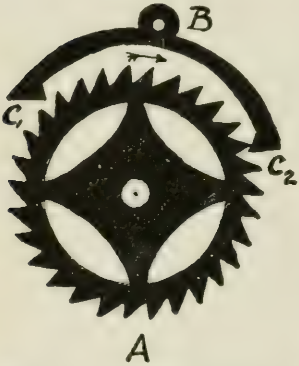


FIG. 142. — A SIMPLE RECOIL ANCHOR ESCAPEMENT.

The technical details in the construction of this escapement must now be considered. The escape wheel may be of any size within reason. The modern tendency is to make it smaller and lighter. The force of the blows on the anchor as it is stopped and thus the wear are less. There is, of course, a practical limit to the smallness. Escape wheels are usually made of brass. The number of teeth may be anything. It depends upon the time of swing of the pendulum and the ratios of wheel to pinion in the

time train. Thirty is a very common number and almost always the number when the pendulum has a time of swing of one second. The teeth are usually pointed and their sides are not usually radial. The inner face generally makes an angle of 10° and the outer face one of 20° with the radius. It is not difficult to lay out or draw an escape wheel. Suppose that its diameter is to be one inch and that there are to be 30 teeth. Draw a circle having a diameter

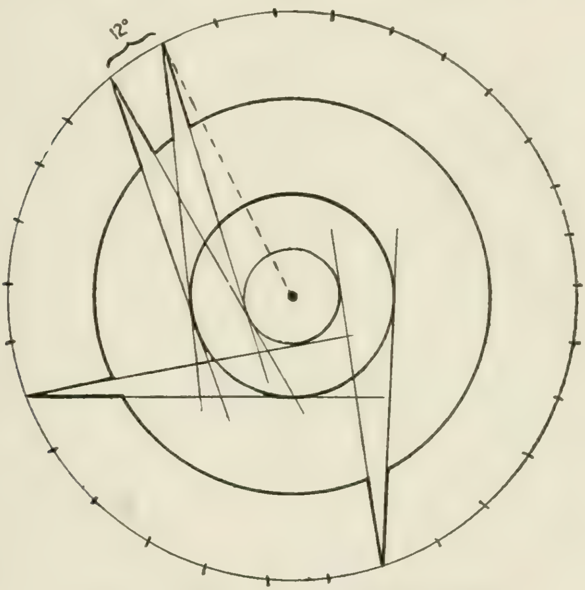


FIG. 143.—LAYING OUT AN ESCAPE WHEEL.

of one inch and divide it into 30 equal parts. It should be remembered that each part will have an angular value of 12°. From one of these 30 points draw two lines, making angles of 10° and 20° (or whatever angles have been determined upon) with the radius. Draw two circles tangent to these lines. The rest of the teeth may now be quickly drawn. From each point draw two lines tangent to these circles and in each case a tooth has been defined. All this is illustrated in Fig. 143, where four teeth are indicated.

The anchor may embrace any number of teeth of the escape wheel from two or three up to one third the total number or even more. A very common way to construct the anchor is to have it embrace one quarter of the number of teeth. Thus if the escape wheel has 30 teeth, then seven

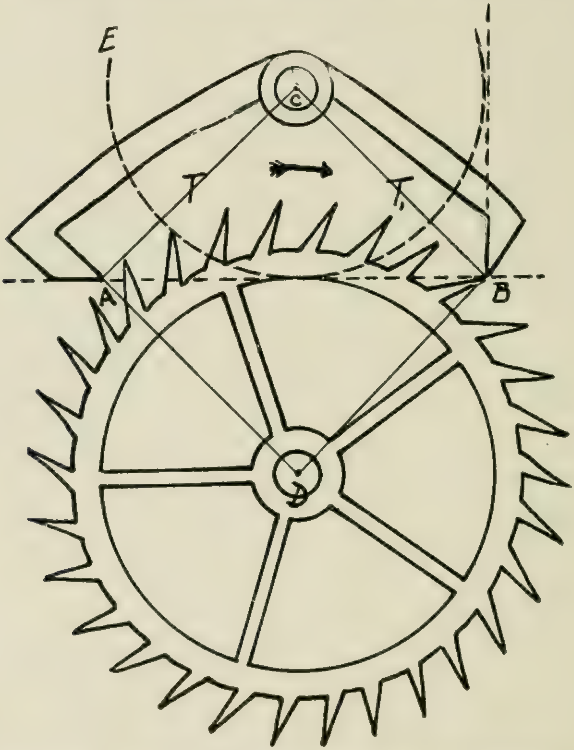


FIG. 144. — LAYING OUT A RECOIL ANCHOR ESCAPEMENT.

and one half are embraced by the anchor. The practical rules for laying out or drawing an anchor may now be stated. Let us suppose to make the problem definite that the escape wheel has 30 teeth and one quarter of them are to be covered by the anchor. The construction is illustrated in Fig. 144. From the two points *A* and *B* which are separated by $7\frac{1}{2}$ teeth and are the two points where the

anchor is to touch the escape wheel, tangents (T and T_1) are drawn to the escape wheel. It will be remembered that a tangent is always perpendicular to a radius. The intersection of these two tangents at C will determine the proper center for the anchor axle. It can easily be shown by plane geometry[1] that the distance between the centers of the anchor and the escape wheel will be 1.4 (more exactly $\sqrt{2}$ or 1.41) times the radius of the escape wheel measured, of course, to the end of the teeth. Many books state the rule this way: that the distance between centers always equals 1.4 times the radius of the escape wheel. This is not correct. It is nearly always true if one quarter of the number of teeth on the escape wheel is covered, but for a smaller or larger number of teeth covered, it varies from perhaps 1.2 up to 1.8. Some books also state that the anchor center is always determined by drawing tangents. This again is not universally true. Having determined the center of the anchor, with a radius equal to one half the distance between centers, describe a circle E. From the points A and B draw tangents to this circle. These will determine the faces of the pallets if they are not curved. If curved they should be made convex. The rest of the anchor outside of the pallets may have any form or shape. In Figs. 46 and 151 another form of recoil anchor escapement is illustrated. Notice in particular the direction of the teeth and the shape of the pallets.

An anchor escapement of the dead-beat form differs but little from one of the recoil form. The escape wheel does not move backwards or recoil but remains stationary or dead when not moving forward. This is accomplished by changing the form of the pallets. It was invented by George Graham about 1715 and is a superior escapement for accurate clocks. The method of laying it out or drawing it is shown in Fig. 145. It is again assumed that the escape wheel has 30 teeth of the same shape as before and that one quarter of them are to be covered by the anchor. The center of the anchor has been determined as before by draw-

[1] The triangle DAC is a right triangle having for angles 90°, 45°, and 45°.

ing tangents T_1 and T_2 and the distance between centers is thus 1.4 times the radius of the escape wheel. There are now four active faces, F_1 and F_2, also S_1 and S_2 for the pallets. The faces F_1 and F_2 are circular and drawn from B as a center. The faces S_1 and S_2 make angles of 60° with the radii R_1 and R_2. To determine their length the angle of swing of the pendulum must be known. In the figure it is assumed to be 4°. Lines are thus drawn from B making an angle of 2° with T_1 and T_2 and these lines with

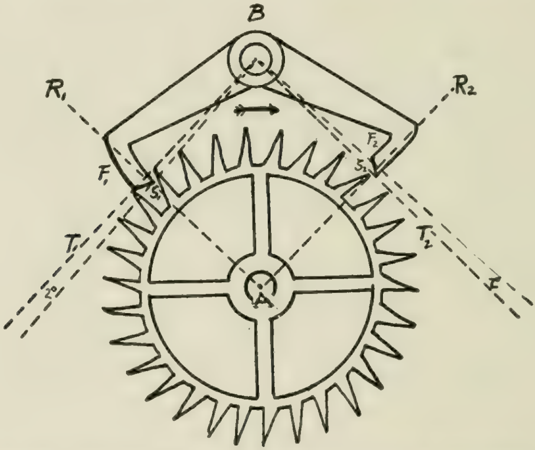


FIG. 145. — LAYING OUT A DEAD-BEAT ANCHOR ESCAPEMENT.

the tangents bound the faces S_1 and S_2. A tooth falls first on F_1 or F_2. The impulse is given on faces S_1 and S_2.

After reading the description of the two forms of the anchor escapement and noticing carefully the illustrations, a natural question to ask is just how the two forms differ. In other words, what constitutes the difference in the horns or pallets of the anchor which causes the one to be a recoil anchor escapement and the other a dead-beat anchor escapement. This can be answered by means of Fig. 146, which illustrates on a large scale the two forms of the pallets or horns. AB and $A'B'$ are described from the axle or arbor of the anchor as a center and an anchor with the four faces

AB, BC and $A'B'$, $B'C'$ would be of the dead-beat form. The teeth of the escape wheel fall first on AB or $A'B'$ and give their impulses on BC or $B'C'$. In the recoil form the faces DB and $D'B'$ upon which the teeth of the escape wheel first fall, must protrude and form an angle with AB and $A'B'$, in order to cause a recoil as the anchor turns. The larger this angle the more the recoil. The impulse faces could remain the same. The corners at B and B' are unnecessary and can be smoothed away, giving the dotted curves DC and $D'C'$. These are the usual forms for a recoil anchor escapement.

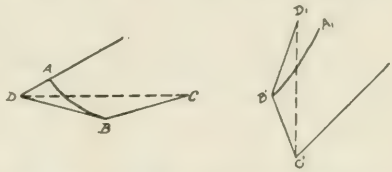


FIG. 146. — FIGURE ILLUSTRATING THE DIFFERENCE IN THE PALLETS OF A RECOIL AND A DEAD-BEAT ANCHOR ESCAPEMENT.

The pin wheel escapement invented by Lepaute in 1753 has had an extended use. It has even been used in some modern factory-made clocks but is not used in any clocks made to-day.

The various escapements have now been fully considered. The remaining parts of the controlling mechanism are the crutch and pendulum. The crutch is a small metal rod or wire which is rigidly attached to the anchor and loosely attached to the pendulum. Sometimes there is a loop which surrounds the pendulum rod and sometimes the crutch ends in a pin which works in a slot in the pendulum rod. A typical crutch is illustrated in Fig. 46. Through it the pendulum moves the anchor and through it the impulse given to the pallets is communicated to the pendulum to keep it swinging.

The pendulum is a very important part of the controlling mechanism and has already been mentioned several times both in this chapter and in previous chapters. It must now be considered in detail. Historically the pendulum was introduced into clock mechanism about 1658. It will be remembered that the credit for the invention cannot be given with certainty to any one person. Most

would give the credit to Huygens, however. The parts of a pendulum to be considered are the support, the method of attaching it to its support, the rod, and the bob. Before taking up these parts something must be said about the time of swing of a pendulum.

The time of swing of a pendulum depends upon its length, the value of gravity at the place, and to a slight extent upon the length of the arc through which it swings. The familiar formula to be found in almost all books on Physics is $t = \pi\sqrt{\frac{l}{g}}$. Here π is a constant and equals 3.14159; t is the time of swing; l is the length of the pendulum; g is the value of the acceleration of gravity and is slightly different at different places, depending upon latitude and elevation above sea level. If we take 32.2 feet for g, which is a fair average value, then the length of the pendulum can be computed from the time of swing or vice versa. The following table gives the computed length for different values of t:

t	l
2 sec.	13 ft. ½ in.
1½ sec.	7 ft. 4 in.
1 sec.	39.1 in.
½ sec.	9.8 in.
¼ sec.	2.5 in.

It is not easy to define exactly what is meant by the length of a pendulum. If a pendulum were a heavy ball suspended by a rod without appreciable mass, then the length would be the distance from the point of support to the center of this ball. In actual pendulums the length is usually defined as the distance from the point of support to the "center of oscillation," which point usually lies a small distance above the center of the bob. In the formula given above the length of the arc of swing has been neglected, or rather it has been assumed that the arc is infinitesimally small.[1] In constructing pendulums there is always a screw thread and a nut at the bottom so that the length may be varied an inch or more. Thus in practice one need not worry

[1] For a full mathematical treatment of the pendulum see books on Mathematical Physics or Mechanics.

over the fact that the exact value of gravity may not be known for the place in question, that the arc may not be infinitesimally small, and that the length of the pendulum cannot be accurately defined. Sufficient leeway is allowed so that the desired length can be found by experiment. Most grandfather clocks have seconds pendulums, that is the length is approximately 39.1 inches. Some tower clocks have pendulums which swing in one and a half seconds. There are only a very few two-seconds pendulums in the world and none longer.

It was first shown by Huygens that if a pendulum were to swing in a cycloid instead of a circle then there would be no "circular error," as it is called. That is, the time of swing would not depend upon the arc of swing. Attempts have been made by means of cheeks or guides to force a pendulum to describe a cycloid. Huygens' arrangement is shown in Fig. 147. It has been found in practice, however, that more troubles are introduced by these guides than are eliminated by their use. They are never used to-day in clock mechanism. Quite a few other devices, including the use of springs and small weights, have been invented for the same purpose, but none of them have been used to any extent.

FIG. 147.—THE PENDULUM ARRANGEMENT OF HUYGENS.

A great deal has been written about making pendulums isochronous, that is, giving them the same time of swing regardless of the arc through which they swing. The following table indicates how much a clock loses per day with a pendulum swinging through different arcs as compared with a clock having the pendulum swinging through an infinitesimal arc.

1°	1.65^s
2°	6.59^s
3°	14.80^s
4°	26.35^s
5°	41.15^s

If a clock is spring-driven the power on the movement changes as the clock runs down. Oil thickens and dust collects and these things change the amount of friction. Thus the power supplied to the pendulum and its arc of swing are bound to change. If the arc drops from 4° to 3° as seen in the table the clock gains 11.55^s per day. This is not a small amount and it might seem that something should be done about it. As a matter of fact there is another thing which complicates the problem. The escapement introduces an error as the power changes and it is thus pendulum and escapement combined which should be made isochronous, and this is practically an impossible problem to handle in theory. What is done in practice is to keep the power and thus the arc of swing as constant as possible.

The chief characteristic of the pendulum support is that it should be very firm and rigid. In most clocks it is a post fastened to one of the plates which hold the movement. Sometimes in the best clocks there are special arrangements to make the support rigid, and this is particularly true if the pendulum is heavy. If a post is used, it is generally slotted and the pendulum spring passes through it.

There are several different ways of attaching a pendulum to its support. These make use of a flexible cord, a wire loop, or a flat spring. The use of a pendulum spring, as it is called, is now almost the universal way. This spring bends, of course, with each swing of the pendulum and should be of a length, size, and thickness to suit the length and weight of the pendulum. In most cheap clocks the metal pendulum rod is simply flattened out and thinned to form the spring and this passes through a slot in the supporting post. In a few good clocks there is an entirely different method of supporting the pendulum. It is hung from knife edges which rest upon agate plates.

The appearance, construction, and material of the rod and bob of the pendulum depend entirely upon whether any attempt is made to compensate for the effect of temperature changes or not. All materials used in the construction of pendulums expand with heat and contract with cold.

Therefore changes in temperature change the length of a pendulum and thus its time of swing. A clock would gain time in winter when it is cold and lose time in summer when it is warm and the difference is by no means small. A clock with a seconds pendulum of brass, if exposed to a change of 180° F. in temperature, would change its rate of running by $1^{m}\ 40^{s}$ per day. In the following table are given the coefficients of expansion of various materials used in constructing pendulums for a change of 180° (that is, from 32° to 212°) Fahrenheit:

Lead	.0028
Zinc	.0028
Aluminum	.0023
Brass	.0020
Copper	.0018
Steel	.0011
Wood	.0004
Nickel-steel (36.1% Nickel)	.00009
Mercury	.0180 in volume x3 = .0540

It will be seen that the expansion of wood is small and that aluminum, zinc, and lead stand high. In the case of certain modern alloys (mostly nickel and steel) the expansion is very small. In the case of mercury, which is a fluid, if it is contained in a vessel which does not change its form or size due to temperature changes, then the rise of the mercury due to heating would be three times the amount given. Five kinds of pendulums must now be considered. We will call them the metal rod, the wooden rod, the gridiron, the mercury, and the alloy pendulum.

In most cheap clocks the pendulum rod is of metal, either brass or steel, and usually the latter. This means that no attempt whatever is made to allow for temperature changes. Such clocks cannot be expected to run well, but, since they are usually cheap clocks, the accuracy is none too great anyway, and the temperature errors are thus not especially noticeable.

Since the expansion of wood is so very small, it is the best material for a pendulum rod. Either deal, white pine, or mahogany are ordinarily used. The wood should be straight grained so that it will not warp and it should be

well baked and then thoroughly shellacked to exclude moisture. Wood is in less favor than metal for cheap clocks because it is not quite as easy to attach the bob and the pendulum spring. If the bob is large, made of lead or zinc, and supported at the bottom, it is possible to almost entirely overcome the effect of temperature changes. If it is a seconds pendulum, then a zinc or lead bob would have to have a radius between six and seven inches to compensate for temperature changes. Six or seven inches of zinc, as will be seen from the table, expand almost exactly as much for a given change of temperature as 46 inches (39.1 inches plus 6 or 7 inches) of wood. This kind of a pendulum is therefore the ideal simple pendulum when the expense of a well-compensated pendulum is to be avoided.

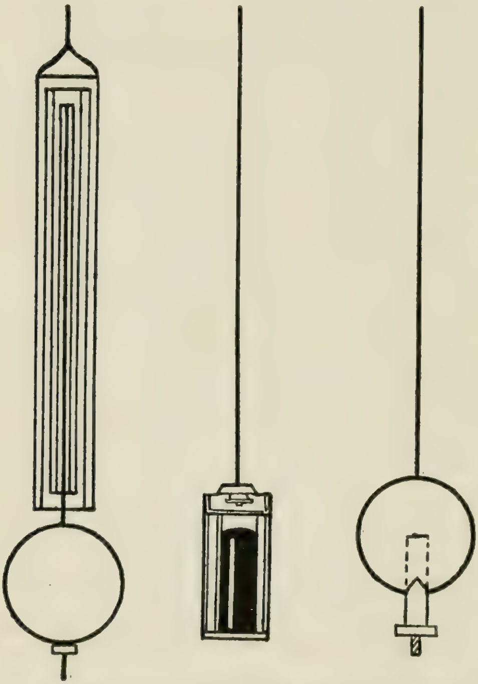


FIG. 148. — THE GRIDIRON, MERCURY, AND ALLOY PENDULUMS.

The mercury pendulum, which was invented by George Graham in 1721, was the first attempt to definitely get rid of the effect of temperature changes. It consists of a metal rod, usually steel, which supports a vessel of mercury which takes the place of the pendulum bob. In Fig. 148 is shown a section of such a pendulum. If the temperature rises the rod lengthens but the mercury expands and rises in its containing vessel. By using just the right amount

of mercury it is possible to make the compensation perfect. The containing vessel for the mercury is made of either glass or cast iron. Iron is preferable because it is less liable to be broken, the mercury can be heated in it to expel air and moisture, it can be more easily attached to the pendulum rod, and it communicates its temperature more rapidly to the mercury within. If it is a seconds pendulum the height of the mercury must be between 7 and 8 inches. If the coefficient of expansion of all the parts and all the dimensions are known it is possible to compute theoretically exactly what the mercury height should be. In practice, however, the final adjustment is made by experiment. If for example a clock gains in heat, then it is overcompensated and a little mercury must be removed. Mercury pendulums are heavy and thus must have a firm support.

The gridiron pendulum was invented by John Harrison in 1726 and consists of either nine, five, or three bars of two different metals, usually steel and brass, so joined together as to resemble remotely a gridiron. In Fig. 148 is shown a section of such a pendulum. Bars 1, 3, 5, 7, and 9 are of steel, which expands the least, while bars 2, 4, 6, and 8 are of brass, which expands more. By getting the lengths just right it is possible to entirely eliminate the influence of temperature changes. This pendulum responds if anything a little more rapidly to temperature changes than the mercury. Sometimes the rods or flat bars are placed one back of the other and loosely joined together. Sometimes tubes are used one inside the other, but the principle is the same.

An alloy pendulum consists of an alloy of several metals, mostly nickel and steel, so chosen that the coefficient of expansion will be the least possible. This was first done by Guillaume, and in Fig. 148 is shown a section of such a pendulum. The coefficient of expansion is so small that compensation can be effected by a few inches of aluminum.

As matters stand at present, all first class, accurate clocks have either mercury, gridiron, or alloy pendulums. Good clocks, particularly those with seconds pendulums,

usually have wooden rods, and large bobs. Cheap clocks have metal rods.

It must not be thought, however, that if a clock has a compensated pendulum all temperature troubles are at an end. If the temperature changes rapidly the rod will respond more rapidly to these changes than the mercury. Furthermore, there is likely to be a small difference in temperature between the top and bottom of a pendulum. Thus the rod may be in one temperature and the vessel of mercury in another. The conclusion of the whole matter is that even if a clock has a compensated pendulum, the temperature should be kept as nearly constant as possible.

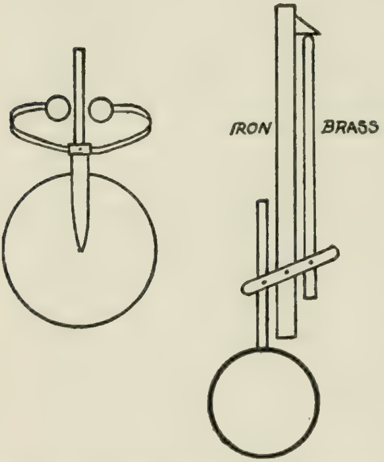


FIG. 149.—TWO INGENIOUS DEVICES FOR TEMPERATURE COMPENSATION.

Other devices have also been invented besides those in use at the present time for taking care of temperature changes. Two of these which are ingenious, but never had any wide application, are illustrated in Fig. 149. The way they work is evident from the figure.

The pendulum bob is usually lens shaped or in the form of a cylinder. The cylinder is used almost exclusively with mercury pendulums. The lens shape offers the least resistance to the air. The material is usually zinc or lead and they are often covered with brass for ornamentation.

There are many imitation gridiron and mercury pendulums. If this is simply to make the pendulum ornate it is well enough but if the attempt is hereby made to trick the unwary into believing that the clock really has a gridiron or mercury pendulum, then it is a despicable deception.

The indicating mechanism consists of the hands and

dial and the under-the-dial mechanism, which is often called the motion work. In fact it is usually called motion work by jewelers and under-the-dial mechanism by the writers on the history of timekeepers.

The earliest mechanical clocks had only one hand, namely the hour hand. Just before 1700, when the accuracy of timekeepers was greatly increased by the introduction of the pendulum and anchor escapement, the concentric minute hand began to make its appearance. If it was used before this time it was on a separate arbor and not concentric with the hour hand. The second hand came still later when accuracy had further increased. At the present time hands of all shapes and sizes and even materials are used. From 1500 to 1800, however, there was a more or less definite sequence of styles for clock hands. Thus an expert by carefully studying the hands of an old clock can form a fair estimate of its age.

The origin of the words *minute* and *second* may be of interest. The fine or minute divisions into which the hour was divided to make the sixty minutes gave rise, of course, to that word. The seconds were for a time called second-minutes, that is, the second fine or minute subdivisions of the hour. Very soon the minutes part of the word was dropped and they became seconds.

The dials were originally of brass and were a fine field for ornamentation. They were often carefully engraved or chased. Particular attention was paid to the four corners outside of the circle of numbers. These are known as the spandrel corners. At first carefully made brass ornaments were attached here, and there was a more or less definite sequence of styles so that the expert can again form an estimate of the age of an old clock from the spandrel corners. Later (between 1700 and 1800) enamel dials came into use and these degenerated into painted wood. The spandrel corners were still decorated and are usually ornamented even at the present time. Both Roman numerals and Arabic figures are used, but Arabic figures are extremely rare except during the last century. The Roman numerals

until recently always radiated from the center of the dial; that is, appeared right side up when viewed from the center. The Arabic figures have been placed both ways; that is, radiating from the center and upright. It is interesting to note that IIII is practically always used instead of IV for four. When this practice arose and the reason for it are not definitely known. There is a story that a famous clockmaker had constructed a clock for Louis XIV, king of France. The clockmaker had naturally used IV for four. When the clock was shown to the king, he remarked that IIII should have been used instead of IV. When it was explained to him that IV was correct, he still insisted, so that there was nothing to do but change the clock dial. This introduced the custom of using IIII for four. This is probably only a story, however, as IIII occurs long before the time of Louis XIV. And this same story is also told in connection with other monarchs. There is one reason why IIII is preferable to IV, and it may have caused the change. On the other side of the clock dial the VIII is the heaviest number, consisting of four heavy strokes and one light one, as it is usually made. It would destroy the symmetry to have IV with only two heavy strokes on the other side. Thus IIII with four heavy strokes is much to be preferred. The change may therefore have been made for reasons of symmetry.

The motion work consists of two so-called cannon pinions and four wheels. These are located just under the dial in the center of the clock. The purpose of the motion work is to drive the hour hand from the minute hand and also to enable a clock to be set. It has been fully described and pictured on page 79. It came into use just before 1700, when the concentric minute hand was added to the clock.

CHAPTER XII

THE STRIKING, CHIMING, ALARM, REPEATER, CALENDAR, MOON-PHASE, AND EQUATION OF TIME ATTACHMENTS TO CLOCKS

In both Chapter V, where the construction of the simplest possible clock was considered, and again in Chapter XI, where the construction of the individual parts of clocks was taken up, it was assumed that there were no attachments. It remains in this chapter to consider the various additions which are often or sometimes made to clock mechanism.

The striking attachment is as old as the mechanical clock itself. In fact the earliest clocks struck the hours before a hand and dial were added to indicate them. At the present time there are two forms of striking mechanism. One makes use of the "count wheel" and the other a "rack and snail." The count wheel is the oldest and goes back to the beginning. The rack and snail form was invented by Edward Barlow in 1676. These two forms are somewhat different and must be taken up separately.

The striking mechanism consists of a spring or weight to furnish the power, a train of wheels, a regulator, a device to start the striking at the proper time, and a device to determine the number of blows to be struck. It is in this last that the two forms of mechanism differ.

The power for the striking mechanism is furnished either by a spring or a weight. If a spring is used it is ordinarily of the same length and size and attached in the same way as the spring which drives the timekeeping part of the clock. There is perhaps one difference and that is the springs used for striking are often of a poorer quality than the springs used for the going part. Clock springs should be carefully tested at the factory. The best ones are used

to drive the timekeeping part and the seconds are used for the striking part, since here slight irregularities are of no account. If a weight is used it generally has the same size and fall as the weight on the time side.

The striking train, as it is called, is exactly analogous to the time train and consists of a series of toothed wheels working into each other. All that has been said about the wheels, pinions, and arbors of the time train could be repeated here. The striking train always occupies the left-hand side of a clock as one faces it and the time train the right-hand side. The number of wheels and pinions in the striking train depends upon the length of time the clock is to run and a little upon the maker.

The regulator is simply a device for preventing the striking train from running too fast. It is almost always simply a fan-fly. That is, on the axle or arbor of the last pinion is mounted a flat piece of sheet metal having an area of one or two or perhaps several square inches. When the striking train is running this beats against the air and keeps it from going too fast. So far the striking mechanism is extremely simple and consists of a driving spring or weight, a train of wheels, and a fan-fly regulator to keep it from going too fast.

The actual striking is done by means of a number of pins set in the face of one of the wheels of the train. These pins raise the tail of the hammer against the action of a spring and as the tail slips past each pin the hammer delivers its blow to the bell or gong.

The device for causing a clock to strike at the proper time consists of the lifting piece or pieces and a post or projection on the central arbor of the timekeeping part. It will be remembered that there is one arbor in a clock which turns in exactly one hour, that this is planted in the middle of the mechanism, and that it is on this arbor that the cannon pinion fits which carries the minute hand. On this arbor there is a projection or post which, as it turns, slowly raises the lifting piece. Finally, when the minute hand reaches 60, the lifting piece slips off the post and the

clock begins to strike. This is the only connection between the running and striking sides of a clock. Thus once each hour the lifting piece is slowly raised and then allowed to fall exactly at the end of the hour.

The device for allowing a clock to strike a certain number of blows and no more or no less is the most vital and complicated part of the striking mechanism. It will be remembered that there are two forms. The count wheel form will be considered first. The essential parts (disconnected) are shown in Fig. 150. *A* is the count wheel which has twelve deep notches and a different number of cogs between each notch. The number of cogs runs from one to twelve and thus it is called a count wheel. This wheel is mounted on its own stud and is entirely disconnected from the striking train. Above it, is the count hook *B*, which can drop into a deep notch and hold it fast. At *C* is shown the cam which is fastened to one of the axles of the striking train and turns with it. It has one large notch and over it is the hook *D* for holding it fast. As the lifting piece is slowly raised by the pin on the center arbor, the hooks *B* and *D* are also raised. They may be considered a part of the lifting piece. Finally, a few minutes before the end of the hour, these hooks have been so much raised that the cam *C* is free and the striking train begins to run. In fact the clock would commence to strike if it were not for the fact that the lifting piece has been raised so high that a part of it strikes a part of the regulator. This preliminary short run of the striking train is what is popularly called the "warning" of a clock. The minute hand now reaches the end of the hour, the lifting piece slips off the post, and the striking train is at last unlocked and free. It begins to run and strike the hour. It is so arranged that the cam makes one revolution during each stroke. At the end of one stroke, that is, one revolution of the cam, the hook *D* tends to fall into the slot and stop the striking train, but in the meanwhile a little pin on one of the wheels or arbors of the striking train has pulled the count wheel forward one cog when it passed it. The hook *B*

thus falls on the edge of the count wheel and not into a notch. This does not allow the hook *D* to fall deep enough since the two hooks are connected, to stop the cam, and thus

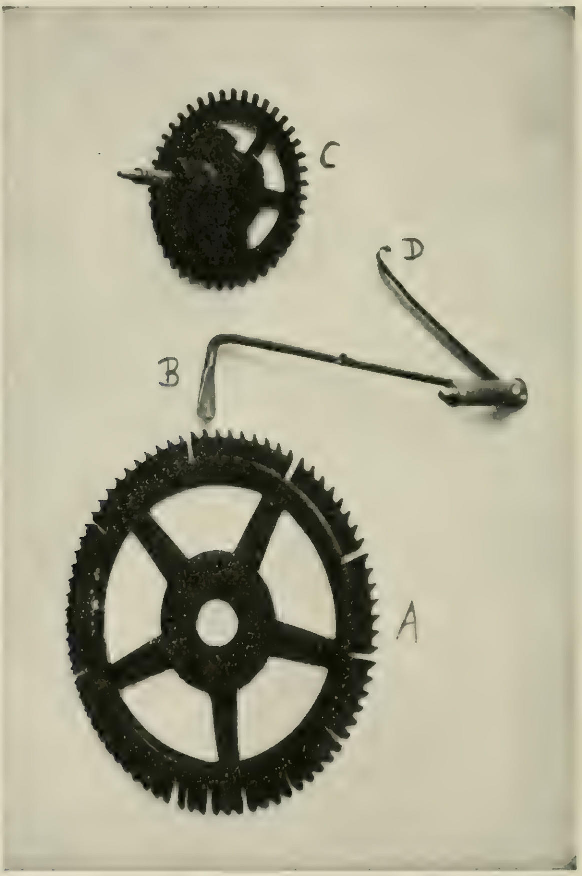


FIG. 150. — THE COUNT WHEEL STRIKING MECHANISM.

it makes another revolution, causing one more stroke on the bell. Finally, the count wheel has been pulled forward far enough to allow its hook to fall into the next deep notch. This allows the hook *D* to catch the cam and the striking

train is once more locked fast. The number of revolutions of the cam (and the number of strokes on the bell)

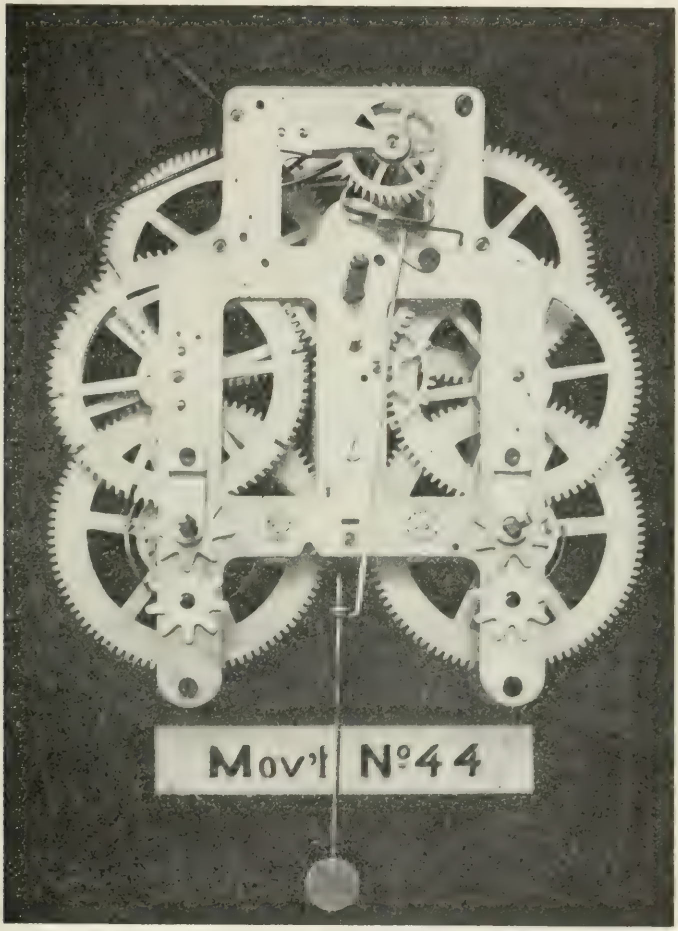


FIG. 151. — THE MOVEMENT OF A MODERN STRIKING CLOCK WITH COUNT WHEEL.
(The Seth Thomas Clock Co.)

has been equal to the number of cogs between the notches on the count wheel. In Fig. 151 is shown a modern striking clock with a count wheel. Most of the parts which

have been mentioned can be made out. The time train is on the right and the striking train on the left. This movement is made by the Seth Thomas Clock Co., of Thomaston, Conn. Incidentally, it may be mentioned that this clock has stop work and a recoil anchor escapement of the so-called American form. The crutch is also very plainly visible. All these matters have been taken up in previous chapters.

The second form of the device for allowing a clock to strike a certain number of blows, and no more or less, makes use of a rack and snail. These two essential parts are easily seen in Fig. 152. It is movement No. 51, as made by the Seth Thomas Clock Co., of Thomaston, Conn., that is here illustrated. It will be remembered that the snail *A* has twelve parts, each of a different size, and that the rack *B* has twelve or more teeth. The snail is attached to the time train (in the center of the movement just behind the hands) and turns with it. In fact it is so attached that it makes just one revolution in twelve hours. There is just as before a post on the central arbor which slowly raises the lifting piece and then allows it to fall at the end of each hour. Here there are thus two connections between the time part and the striking part, namely, the snail and the post. As the post gradually raises the lifting piece, the rack is at last freed and it falls down until a point attached to it strikes the snail. The amount that the rack can fall is thus determined by the position of the snail. If it is to strike twelve, it falls the greatest amount. This falling of the rack constitutes the "warning." Finally, just at the end of the hour the striking train is released as the lifting piece slips off the post. As the clock strikes a little pin *C* "picks up" or "gathers in" one cog of the rack for each stroke of the bell and the striking train is again locked fast when the rack has been pushed back to its former position. The rack acts like a part of a count wheel. The snail by its position simply determines how much of the rack is to be used. This form is a little more complicated than the other but it has one very decided advantage. The striking

of each hour is absolutely independent of what has gone before. If, due to some little slip of the mechanism, the clock did not strike right at a given hour, the next hour will nevertheless be struck correctly. This is of course not true of a count wheel. There is thus no need in a rack and snail

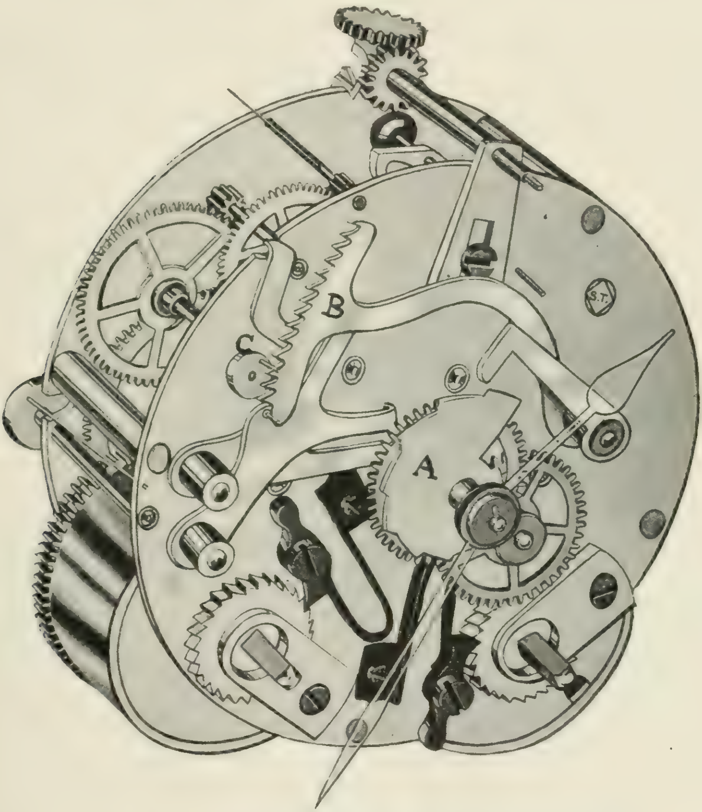


FIG. 152. — A STRIKING CLOCK WITH RACK AND SNAIL.
(The Seth Thomas Clock Co.)

striking clock of any device for "striking the clock round" by hand; it simply cannot strike wrong.

The chiming attachment. — Some clocks not only strike the hours but have chimes as well. There are of all de-

grees of complexity. The very simplest is a single stroke at the half hour on the same bell upon which the hours are struck. This can be accomplished with either a count wheel or a rack and snail clock by a very simple modification of the mechanism. The half hour can also be struck directly. A second post may be placed on the central arbor just 180° from the one which causes the hours to be struck. This second post can raise the tail of a hammer directly and thus cause the half hours to be struck. If it is done this way, then they may be struck on a different bell or on the same bell with a different force.

Some clocks strike one at the quarter, two at the half, three at the three quarters, and four or perhaps many more just before the hour. Often several different bells are used. Sometimes tunes are played, and one may even have the choice of the tune from several. All these arrangements require a third train, usually called the chiming train. When this is the case, the time train is generally placed in the center, the striking train on the left, and the chiming train on the right. The chiming mechanism consists of a spring or weight to furnish the power, the train, some form of regulator, a device just as before for starting the chimes at the proper moment, and a device similar to a count wheel or a rack and snail for determining how long the chiming train shall run. The chiming mechanism is thus very similar to and fully as complex as the striking mechanism. The actual striking of the bells is done by means of a chime barrel which is a cylinder of brass in which pins are set. As this revolves these pins catch the tails of the hammers at the right time and in the right order. This determines how many and which bells are to be struck.

In Fig. 153 is illustrated the movement of a highest grade Westminster quarter hour chime and hour strike clock. It will be noticed that it has the rack and snail striking mechanism and that five bells or gongs make up the chimes as judged by the five hammers. This is movement 113 A, as made by the Seth Thomas Clock Co., of Thomaston, Conn., to whose kindness these illustrations are due.

The alarm attachment. — There are probably more alarm clocks than striking clocks. Historically one is as old as the other. The mechanism necessary for an alarm is

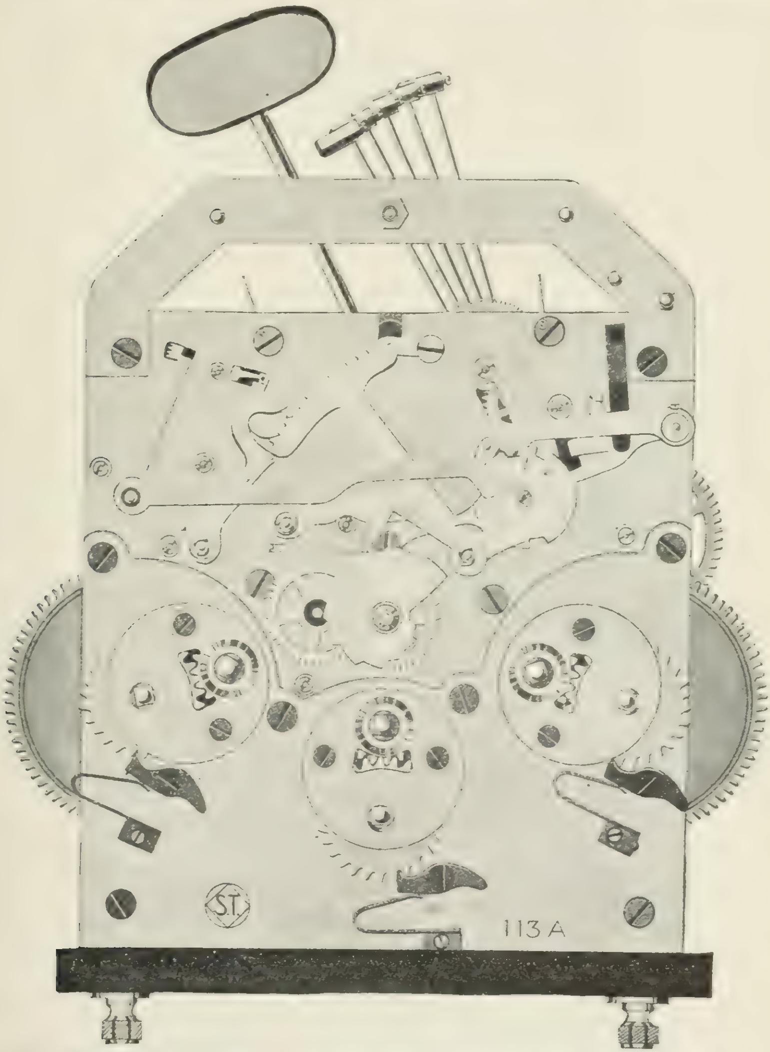


FIG. 153. — THE MOVEMENT OF A MODERN STRIKING AND CHIMING CLOCK.
(The Seth Thomas Clock Co.)

quite similar to that for striking. It is somewhat simpler, however, because there is no need of a device for determining how many strokes shall be given. An alarm clock simply keeps on ringing until it runs down or is shut off. The alarm mechanism consists of either a spring or weight to furnish the power, a train, usually some regulator, and a device for starting the alarm at the proper moment. The first three parts are practically identical with the corresponding parts of the striking mechanism. The alarm may be set for any moment during a twelve-hour period. This requires a slight modification in the starting mechanism. But, just as before, a piece slips off a post or a pin falls into a slot at the proper moment and thus starts the striking.

The repeater attachment. — A repeating clock is one which will repeat or strike over again the hour whenever a certain string or chain is pulled or a knob is pressed down. The repeater was invented by Edward Barlow in 1676. Such a clock is in good part only a curiosity and yet it has a real use at night for ascertaining the time without seeing the dial. This was particularly useful before artificial illumination was as easy as at present and before luminous dials had been invented. A striking clock with a rack and snail striking mechanism is really a repeater. Thus when Barlow invented one he had also invented the other. All that is necessary is to be able to do by hand what the clock does automatically each hour — that is, to raise the lifting piece and then allow it to fall. It can be easily arranged so that this can be done by pulling a string or pressing a knob. An hour repeater thus requires practically no additional mechanism of any kind.

There are repeaters, however, which strike the quarters and even the minutes as well as the hour, and more than one bell or gong is used to distinguish between them. The necessary mechanism is quite complicated but the underlying principle is always the same. It is a series of snails connected with the time train which by their position always determine how many blows are to be struck.

The calendar attachment. — Many clocks not only indicate the hour, minute, and second but the larger subdivisions of time as well, such as the day of the week, the day of the month, and the month. These are often called calendar clocks. At the present time the number of newly made calendar clocks is very small compared with the total number of clocks made. The old-fashioned grandfather clocks are, however, mostly calendar clocks. Historically the calendar attachment is about as old as clock mechanism. It will be remembered that the small, simple clock for domestic purposes did not appear until after 1500. The early clocks were expensive, rare, and very intricate. There was a tendency to add as much as possible and thus the calendar was nearly always indicated. It is impossible, therefore, to say who first added the calendar attachment to a clock. It was certainly done before 1400.

At present the simplest possible calendar clock has a hand concentric with the hour and minute hands which goes round the dial in a month and indicates the day of the month. The necessary mechanism is extremely simple and can be driven directly by the motion work. It will be remembered that one wheel of the motion work turns in twelve hours and thus only three more wheels or pinions are necessary to turn a hand once in 31 days. It is so simple that ordinary nickel clocks sometimes have this attachment. At the end of the short months, February, April, June, September, and November, it is necessary to set the hand forward to make it correct for the next month.

Many clocks indicate the day of the week, the day of the month, and the month. This is the usual arrangement with the old grandfather clocks. The necessary mechanism is of two kinds and may be called the simple calendar mechanism and the automatic calendar mechanism. In the first the day of the month must be set right by hand at the end of all short months. In the second it is done automatically by the clock and even leap year is taken care of.

The simple calendar mechanism is shown in Fig. 154. *M* is the wheel in the motion work which turns once in

twelve hours. Wheel *A* has twice as many cogs and thus turns once in a day. To *A* is attached a pin which works in a slot in the three-armed lever *N*. This lever is thus moved to the right and to the left in the course of a day. The wheel *B* has seven teeth and to its arbor is attached the hand which on the dial is to indicate the day of the week. It is evident that it is moved forward one cog each day. It is held in place by the ratchet and spring at *E*. The wheel *C* has 31 cogs and to its arbor is attached the hand which on the dial is to indicate the day of the month. It is evident that it is moved forward one cog each day. It is held in place by the ratchet and spring at *F*. To the wheel *C* is attached a pin which at the end of each revolution pushes the lever *G* and advances the wheel *D* one cog. This wheel has twelve cogs and to its arbor is attached the hand which on the dial indicates the month. It is also held in place by a ratchet and spring at *H*. It will be seen that at the end of all short months the day of the month hand must be set forward and made right. It will also be seen that the calendar work goes forward by jumps as it should and not by a steady motion, as is the case with the hour, minute, and second hands.

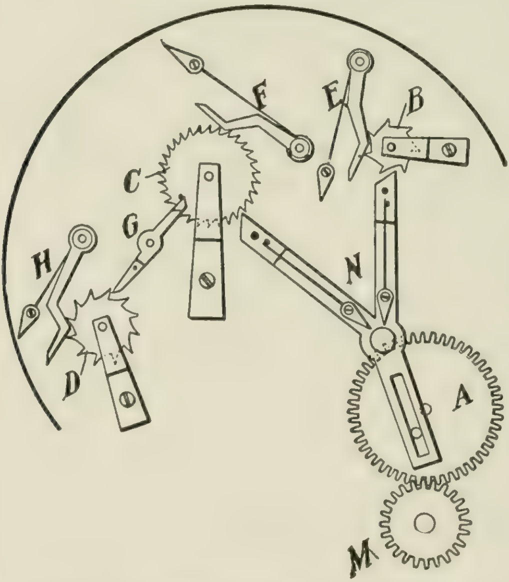


FIG. 154. — SIMPLE CALENDAR MECHANISM.
(From Goodrich, *The Modern Clock.*)

The automatic calendar mechanism is shown in Fig. 155. The action is evident when one considers that one wheel turns in a day, one in a month, and one F in four years. The short months and leap year are taken account of by the notches of different depths in the otherwise smooth periphery of the four year wheel. These allow the projec-

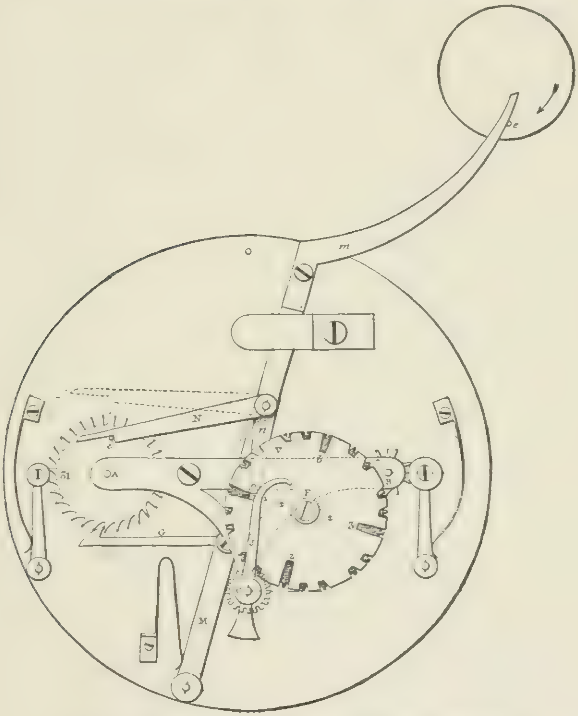


FIG. 155. — AUTOMATIC CALENDAR MECHANISM.
(From SAUNIER, *Treatise on Modern Horology.*)

tion on M to come back farther to the right and thus more pins are pushed forward.

The moon phase attachment is not often added to clocks at present. It is often found, however, in the old grandfather clocks and new ones built on the old lines. It sometimes takes the form of a hand moving over a dial

and indicating the moon's age reckoned from new. It more often takes the form of a moon which appears to gradually come into view through a circular opening, becomes fully visible, and then gradually disappears again, thus in a way actually showing the changing phases of the moon as they occur. The last method is often spoken of as the Brocot form. This is in honor of Achille Brocot, a very skillful clockmaker of Paris who was born in 1817 and died in 1878. Sometimes the moon moves into view from behind a semicircular disc, becomes fully visible and then slowly disappears behind another semicircular disc on the other side. This is the more usual way in modern grandfather clocks. The phases of the moon are shown in connection with quite a few of the grandfather clocks illustrated in Chapters X and XX.

Perhaps a slight digression is necessary here to take up the changes in the phase of the moon. Four phases are recognized: new, first quarter, full, last quarter. From new to first quarter the moon appears as a crescent; from first quarter to full it is gibbous; from full to last quarter it is gibbous; from last quarter to new again it is a crescent. The average time from new moon to new moon again, or from full to full, is 29.530588 days or 29 days, 12 hours, 44 minutes, 2.8 seconds.

If a hand is to move over a dial the problem is to make it complete its revolution in this time. The simplest possible approximation to it is to place a single tooth or pin on an arbor turning in twelve hours, which drives a wheel of 59 teeth by jumps. This would make the time of revolution $29\frac{1}{2}$ days, which is only a rough approximation. The two following are very much better and in fact fairly close to the time: a pinion of 6 or an arbor turning in one hour, driving a wheel of 91, with a pinion of 9 on its arbor driving a wheel of 91, with a pinion of 37 on its arbor driving a wheel of 171; or a pinion of 15 on an arbor turning in 24 hours, driving a wheel of 98, with a pinion of 25 on its arbor driving a wheel of 113.

In the Brocot form there is a circular disc painted white, cream, or gilt with three dark blue circles on it. This

shows through a circular opening in the dial (see Fig. 157). This disc turns in three lunations, that is, in 3 × 29.530588 days. It is moved by a pinion of 10 on an arbor turning in a week, driving a wheel of 84, with a pinion of 75 on its arbor driving a wheel of 113.

In another form of the moon phase mechanism the circular disc has two bright moons on a dark background and turns once in two lunations. This is the method when the moon swings into view from behind a semicircular disc.

The equation of time attachment is almost never added to a clock at the present time. Most of the people who use clocks do not even know what the equation of time is. This was fully taken up in the first chapter and it will be remembered that the equation of time is the difference between true solar time and mean solar time, that its largest value is a little less than 19 minutes, that it is zero four times a year at irregular dates, and that its value for the same date in different years is very nearly though not exactly the same. The importance of the equation of time attachment goes back to the days when mean solar time, not standard as at present, was the universal time and sun-dials, giving true solar time, were much used. The attachment is to be found on many old intricate clocks and a few grandfather clocks of more recent date. An equation of time clock nearly always has the calendar attachment as well.

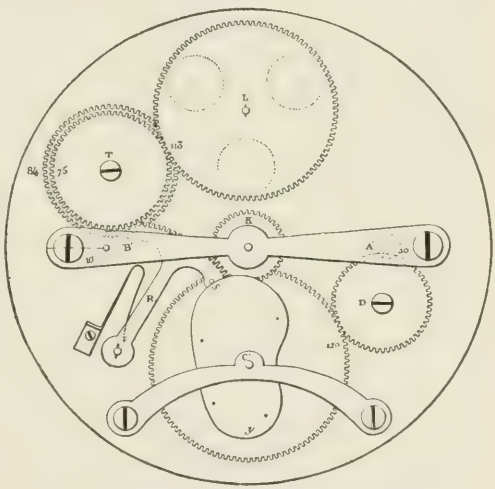


FIG. 156. — EQUATION OF TIME MECHANISM.
(From SAUNIER, *Treatise on Modern Horology*.)

The equation of time is ordinarily indicated by a hand which moves backward and forward past the XII on the

dial and usually has a separately divided arc to give its value. It might seem that the necessary mechanism would be quite complicated, but it is really very simple. As shown in Fig. 156 the mechanism consists essentially of an irregular kidney-shaped cam *y* attached to an arbor which turns once in a year. If it is a calendar clock, then such an arbor probably exists for the calendar mechanism. A post *s* attached to the lever *R* is held against the edge of this cam by a spring. The lever has a rack which gears with a pinion attached to the arbor which carries on the dial

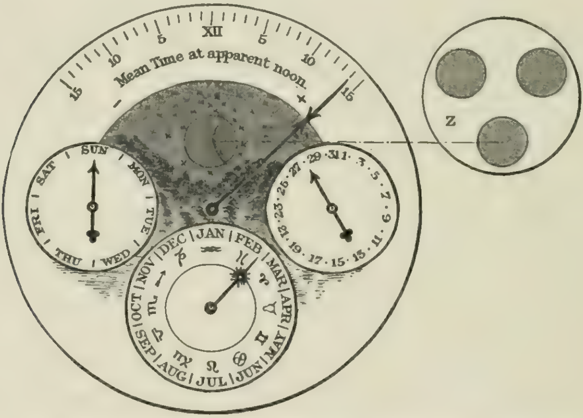


FIG. 157.—THE DIAL OF A CLOCK INDICATING THE MOON PHASES, THE EQUATION OF TIME, AND A PERPETUAL CALENDAR.
(From SAUNIER, *Treatise on Modern Horology.*)

the hand for indicating the equation of time. Thus as the cam turns, the hand moves backward and forward. The number of teeth in the rack and pinion is immaterial, as that will simply determine how far the hand shall swing each side and thus how the arc should be graduated. The all-important thing is the shape of the cam, and this must be so made as to give correct values for the equation of time.

In Fig. 157 is shown a part of a dial indicating the equation of time, the phases of the moon according to the Brocot method, and a perpetual calendar. Figs. 155 and 156 show the mechanism necessary for this dial.

CHAPTER XIII

THE HISTORY OF WATCHES FROM 1600 TO 1800

This chapter and the next two are closely related. This one deals with the history of the watch from 1600 to 1800; that is, from the first use of a *pocket* watch to what is practically the beginning of modern times. In the next chapter the history and construction of the individual parts of watches are considered and the last chapter in this series of three takes up attachments to watches and complicated watches. If Chapter VIII on the construction of the watch of to-day and Chapter IX on the history of spring-driven timekeepers from 1500 to 1658 have been forgotten, it would be well to read them again as an introduction to these three chapters. The five chapters which have been mentioned form a connected treatise on the watch and could be read independently of the rest of the book.

It will be remembered that the portable timekeeper was made possible by the invention of the mainspring as the driving power by Peter Henlein of Nürnberg in 1500. The first clock-watches were quite large, several inches in diameter and drum-shaped. That is, they looked like cylindrical boxes. Later they became smaller and the corners were rounded off, thus giving rise to the circular watch. But there was nearly always a projection from the case opposite the stem. They also became many sided and oval and the oval ones were spoken of as Nürnberg eggs. At about this same time (just before 1600) the craze for unusual forms and ornate cases was at its height. There were watches (called toy watches) in the form of books, death's-heads, animals, fruit, stars, flowers, insects, padlocks, crosses, and cockle-shells. Watches of these different kinds were illustrated in Chapter IX.

All these were not *pocket* watches. They were too

large, the form was too irregular, and furthermore, pocket watches were not the fashion. Watches were kept on a table, or attached to the clothing, or worn on chains around the neck. About 1600 the desire arose for a *pocket* watch, and they were immediately made of a form and size to be so used. Thus the history of the modern *pocket* watch begins about 1600. Why there was the sudden desire to conceal the watch from view cannot be explained. Possibly it was to secure greater protection. Perhaps it was the desire for Puritan simplicity in dress. Fobs came into fashion about this time. The word fob comes from the German word "fuppe," meaning a small pocket. Pockets were used before this time. A line in Shakespeare's "As You Like It" runs "And then he drew a dial from his poke." This may have been a small sun-dial, but at any rate pockets were in use.

What has been said about putting the watch in a pocket applies almost entirely to the watches of gentlemen. Ladies used chatelaines until nearly 1800, and they were a rich field for ornamentation. If not worn on chatelaines they were attached to the clothing or "left on a table" — a custom which has persisted even to the present day.

The pocket watch in 1600 was usually many-sided, oval, or circular in shape and not large in diameter. It was fairly thick, however, as compared with the modern watch. There was usually but one case made of brass but sometimes of gold or silver. It was chased and engraved and sometimes pierced to show the dial numbers. There was but one hand and the dial was usually of brass. Both the front and back covers of the case were often hinged. Then the movement was held in the case by means of little pins extending from the dial and fitting into corresponding sockets in the case. Sometimes only the front cover was hinged. Then the movement was also attached by a hinge so that it could be raised up for winding. The watches illustrated in Figs. 90 to 93 and 102 to 105 may be considered typical of the appearance of the watch when it first began to be carried in a pocket.

The watch movement was made of brass and steel. The mainspring was nearly always provided with the fusee invented by Jacob Zech of Prague in 1525. The watch usually ran from twelve to sixteen hours. The time train consisted of one less wheel and pinion than the modern watch contains. The controlling mechanism consisted of foliot balance, verge, and crown wheel. There was no balance spring to control the motions of the balance. Possibly a straight hog's bristle was used in a few watches to curb the motions of the balance. There was only the hour hand, so there was no motion work. Screws which had come into use about 1550 were used to fasten various parts of the movement together, but wedges and pins were still in common use. There were no jewels.

These watches were very often striking or alarm watches and sometimes had calendar, moon-phase, and equation of time attachments. The accuracy was small. It is doubtful if they would run much better than an hour or two a day.

In tracing the development of these first pocket watches of 1600 down to the present day, it will be better to take up the changes in the case and in the movement separately.

Watch cases from 1600 to 1800. — Watch glasses began to be used about 1610. At first they were flat and rather thick and held in place by split bezel rings. Later they became higher and more rounded. Until modern times, however, they do not play an important part. Glasses were used for clock-watches and table clocks a little earlier than for pocket watches. They were used both as coverings for the dial and as side panels for the cases.

The shape of the case also changed greatly just after 1600. It will be remembered that the circular watch had made its appearance just before 1600, but that there was nearly always a projection from the case opposite the stem. By 1650 practically all watches were circular watches and the projection had disappeared. They were now pocket watches and had the form of the watch of to-day.

A tremendous change in the casing of watches was brought about by the use of enamel and enamel painting.

FIG. 158. — AN ENAMELED WATCH, BY AUGUSTE BRETONEAU, DATE ABOUT 1638.

FIG. 159. — AN ENAMELED WATCH, BY GOULLONS OF PARIS, DATE ABOUT 1670.

FIG. 160. — A WATCH, BY GOULLONS.

FIG. 161. — AN ENAMELED WATCH, BY G. GAMOD À PARIS, DATE ABOUT 1660.

Shortly after 1600 enamel began to be used and enamel painting came in just before 1650. For the next century and more, watch cases were adorned with the most beautiful miniatures. They were to be found on both the outside and inside of the case, around the edge, and on the dial. The enamel painters of Paris and of Blois in France seem to have been especially skillful and perhaps the two brothers Jean Pierre and Ami Huaud (Huaut or Hualt) are better known than any others. Eight of these watches are pictured in Figs. 158 to 165.

Description: Fig. 158 — A watch by Auguste Bretoneau of Paris — date about 1638 — beautifully enameled case with four scenes representing the chase of the Calydonian bear — small hunting scenes around the edge of the watch — two cherubs in landscape within the numeral ring — $2\frac{1}{8}$ inches in diameter. Fig. 159 — A watch by Goullons of Paris — two representations of the Holy Family, the rest are landscapes — $2\frac{1}{4}$ inches in diameter. Fig. 160 — A watch by Goullons of Paris — date about 1680 — four scenes from the story of Antony and Cleopatra — around the edges are landscapes — within the numeral ring two women with a cornucopia of fruit — diameter $2\frac{1}{2}$ inches. Fig. 161 — Movement signed G. Gamod à Paris — date about 1660 — a scene from the story of Antony and Cleopatra. Fig. 162 — French, seventeenth century — scenes outside are from the story of Rebekah at the well — those on the inside show landscapes. Fig. 163 — A watch by Chevalier & Cie of Geneva — date about 1750. Fig. 164 — A watch by Abraham Louis Bréguet — date about 1800. Fig. 165 — The dial and inner case show landscapes — maker, Nicholas Bernard à Paris — date about 1700 — diameter $2\frac{1}{2}$ inches. The first five watches are in the Metropolitan Museum of Art in New York City, a part of the J. Pierpont Morgan collection. The next two are in the Museum of Fine Arts in Boston. The last one is in the South Kensington Museum in London.

It must not be thought, however, that all the pocket watches during this period had enamel cases. It was the

FIG. 162. — AN ENAMELED WATCH — FRENCH, SEVENTEENTH CENTURY.

FIG. 163. — AN ENAMELED WATCH, BY CHEVALIER & CIE, OF GENEVA, DATE ABOUT 1750.

FIG. 164. A WATCH, BY BRÉGUET, DATE ABOUT 1800.

FIG. 165. — AN ENAMELED WATCH, BY NICHOLAS BERNARD À PARIS, DATE ABOUT 1700.

prevailing fashion, particularly in France, but there were plain cases of brass, silver, or gold.

A great many of the artistically decorated enamel watches and practically every watch with a plain case was provided with an outer protective case to keep it from being marred and scratched. Thus during this period watches came to have two cases, often called pair cases.

The loose outer or protective case was made of brass or wood, or of tortoise-shell, fish skin, or shagreen. When these soft materials were used they were generally placed on a metal foundation. Brass and shagreen were probably the favorites. Sometimes there was in addition a thin inner case, usually of gold, to hold the movement. If the movement was held in this way, then the watch had three cases.

If the protecting case was of brass it was usually chased, so that the figures stood out in bold relief. This is known as repoussé chasing.

Shagreen is either horse hide or shark skin finished in a peculiar way and colored green. Britten says: "The true shagreen is a remarkably tough kind of leather, made chiefly at Astrachan from the strong skin that covers the crupper of the ass or horse. In its preparation a peculiar roughness is produced by treading into the skin hard round seeds, which are shaken out when the skin has been dried; it is then stained green with copper filings and salammoniac, and the grains or warts are then rubbed down to a level with the rest of the surface, which thus presents the appearance of white dots on a green ground. The skin of the shark and of various other fishes, when properly prepared, formed an excellent covering, being thin and durable. This if dyed green was also known as shagreen."

When tortoise-shell, fish skin, or shagreen was used it was ordinarily studded with silver or gold nails in geometric or other patterns. This is called piqué ornamentation. In Figs. 166 to 169 a few of these protective outer cases are shown.

Description: Fig. 166 — A watch by Thomas Tompion, London, 1639–1713 — inner case of silver, perfectly plain —

FIG. 166. — A RED TORTOISE-SHELL OUTER CASE FOR A WATCH, BY THOMAS TOMPION.

FIG. 167. — AN ALARM WATCH, BY EDUARD EAST, WITH LEATHER OUTER CASE.

FIG. 168. — A WATCH, BY NICOLAS MASSY, OF BLOIS, WITH LEATHER OUTER CASE.

FIG. 169. — A WATCH, BY DANIEL QUARE, WITH OUTER CASE OF BROWN LEATHER.

outer case of red tortoise-shell piqué with silver studs and decorated with design in silver of wreath — $2\frac{1}{4}$ inches in diameter. Fig. 167 — An alarm watch by Edward East, London, 1615–1701 — outer case of leather piqué with silver stars and crescents — rows of holes in order that the alarm might be heard — $2\frac{1}{8}$ inches in diameter. Fig. 168 — A watch by Nicolas Massy of Blois, 1623–1683 — outer case of leather piqué with gold studs — diameter $1\frac{3}{8}$ inches. Fig. 169 — A watch by Daniel Quare, London, 1649–1724 — inner case plain silver, outer case brown leather piqué with gold and silver studs — $2\frac{1}{4}$ inches in diameter. These watches are all in the Metropolitan Museum of Art in New York City, a part of the Morgan collection.

In Figs. 170 to 172 are illustrated three watches in plain cases and the protective outer case which goes with each.

Description: Fig. 170 — An oval watch by Samuel Linaker, London — date about 1610 — inner case plain silver — outer case also plain — $1\frac{5}{8}$ by $1\frac{3}{8}$ inches — Linaker was one of the first assistants of the Clockmakers' Company. Fig. 171 — A repeater watch by Thos. Mudge, London, 1715–1794 — inner case plain, outer case tortoise-shell with pierced goldwork — diameter 6.7 cm. Fig. 172 — A watch by Richard Street, London, about 1715 — the outer protective case is of shagreen.

The first watch is in the Metropolitan Museum of Art in New York City and the last two are in the Museum of Fine Arts in Boston.[1]

Between the outer protective case and the inner case a little circular pad of velvet or muslin was inserted. The muslin was often adorned with needlework. A circular piece of paper called a "watch paper" was sometimes used, and on these appropriate rhymes were inscribed. Collections of these watch papers have been made. Some watchmakers furnished them free of charge as advertisements.

The elaborately decorated enamel watches continued to

[1] Other illustrations from other collections and from museums in foreign countries could have been chosen. The preference has always been given to American public collections, as these are more accessible to the readers of this book.

FIG. 170.—AN OVAL WATCH, BY LINAKER, WITH PLAIN OUTER PROTECTIVE CASE.

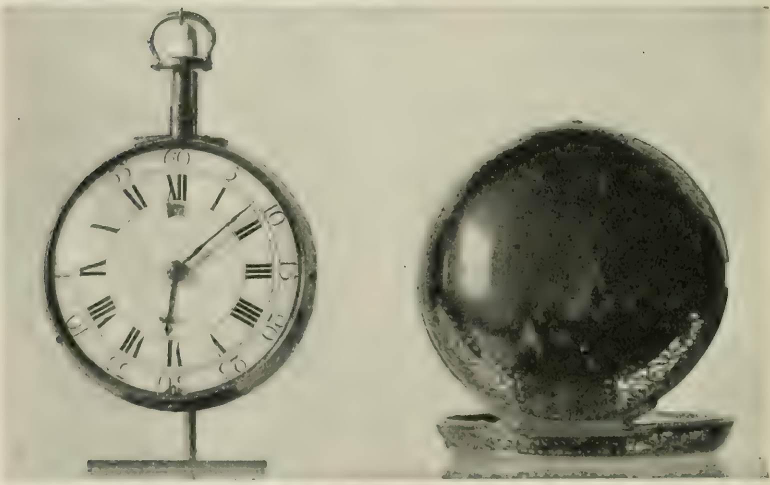


FIG. 171.—A REPEATER WATCH, BY THOS. MUDGE, WITH AN OUTER CASE OF TORTOISE-SHELL.

FIG. 173.—A "TOY" WATCH IN THE FORM OF A RED BUG.

be in fashion until 1800 or somewhat later. Then the watch began to be a thing of use and not a field of ornamentation. It became thinner and continued to have two cases, an inner plain one to hold the movement and an outer one

FIG. 172. — A WATCH, BY RICHARD STREET, WITH A SHAGREEN PROTECTIVE CASE.

to receive the wear. There was no enamel. The outer case was either chased or decorated with "engine turning." This consists of many circular curves and is said to have been introduced by Francis Guerint of Geneva in 1780. It is a simple method of ornamentation and does not show scratches.

The persistency of the older forms. — Although enamel painting came in just before 1650 and for more than a century continued to be a fashionable and much desired method of ornamenting a watch case, it must not be supposed that the earlier forms of watch cases fell at once and completely out of use. This is never the case. The older forms always persist alongside of the new. Oval watches and "toy" watches continued to be made. In fact it is probably during this later period that the most artistically pleasing and mechanically perfect examples are to be found. One is illustrated in Fig. 173, page 222. It is in the form of a red enameled bug set with diamonds and with emerald eyes. It is 4.4 inches long and 2.5 inches wide, and was loaned to the Museum of Fine Arts of Boston by Mrs. Eman L. Beck.

Changes in the movement also took place during these two centuries and they greatly increased the accuracy of running. The first change which was only a slight one was the introduction of the flexible chain instead of the catgut on the fusee by Gruet, a Swiss, in 1664, or perhaps earlier. The fusee continued to be used with the mainspring during this period in most watches. It is only in modern times that it has been abandoned. Mainsprings are now better made, they are much longer, and the adjustment to isochronism is made in the hairspring, so that the fusee is no longer necessary.

The next great improvement was the introduction of the balance spring (now often called the hairspring) in connection with the balance. At first, shortly after 1600, there were a few watches in which a straight hog's bristle was used to curb the motions of the balance. In 1658 Robert Hooke began experimenting with a straight metal spring to replace the hog's bristle. In 1674 John Hautefeuille and Christian Huygens independently of each other used a spirally coiled metal spring which was a great improvement. There is a controversy as to who first invented the balance spring. Perhaps it would be better to say that the balance spring was invented about 1675, due to the experiments of Hooke, Hautefeuille, and Huygens. Later, as the escape-

ment improved, it was made smaller and longer and given more turns until it became the balance spring as it is used to-day.

The greatest improvements were made in the most vital part of any timekeeper, namely the escapement. The cylinder escapement to replace the old verge escapement which had been in use for so many centuries was invented by Thomas Tompion in 1695. It was much improved by George Graham in 1720. In 1724 the duplex escapement was invented by Jean Baptiste Dutertre. This was improved by Pierre LeRoy in 1759. In 1750 the detached lever escapement was invented by Thomas Mudge. Many other escapements were thought out and used to a slight extent, but these three, the cylinder, the duplex, and the detached lever, were destined to stand the test of time and are to-day the only escapements used in watches.

In 1700 or a little later, the use of jewels was introduced by Facio (or Facie), and this was destined to greatly increase the accuracy of running. Nicholas Facio, a native of Basle, was born in 1664 and came to England in 1687. Just before 1700 he was elected a Fellow of the Royal Society. In 1704 a patent was granted to Nicholas Facio, Peter Debaufre, and Jacob Debaufre for the use of jewels in the pivot holes of watches and clocks. Shortly after they applied to Parliament for a Bill to extend their patent. This they did not secure and the chief evidence against them was an old watch by Ignatius Huggeford, which had a stone fixed in the balance cock. The interesting part of the story is that years later when the Huggeford watch was carefully examined it was found that the stone was an ornament only and was not a watch jewel in any sense. Facio settled in Worcester in 1720 and died there in 1753.

The use of jewels and the newer escapements so greatly increased the accuracy of watches that about 1700 the minute hand and the under-the-dial mechanism began to be added to watches. The second hand came still later, when the accuracy had further increased.

These two centuries, then, from 1600 to 1800, saw the

discontinuance of the fusee, the introduction and development of the hairspring, the substitution of better escapements, the use of jewels, and the introduction of the minute and second hands. The watch has become practically the watch of to-day.

The accuracy of antique watches. — This is a question which is easily raised but not easily answered. It is usually considered that De Vick's clock of 1360 kept time within about two hours a day. The clock-watches of 1500 had exactly the same escapement and construction. The escapement consisted of the foliot balance, verge, and crown wheel. In a clock-watch, since the parts were so much smaller, the relative accuracy in their construction was probably less than for a large clock. One would thus expect them to keep poorer time than a clock, that is, to keep poorer time than a couple of hours a day. No wonder that sun-dials, sand-glasses, and water clocks were preferred!

A great improvement in accuracy was brought about by the introduction of the balance spring, which took place in 1674. It is thus a very interesting question as to how accurately the watch ran in 1700. Of course it would make a very great difference whether the watch was carried in the pocket or on the person or left quietly on a table. There are practically no statements in memoirs or old diaries to show how accurate watches were at this time.

The *Souvenirs of Duguay-Trouin*,[1] as Professor Bouasse of the University of Toulouse has so interestingly brought out, throw some light on the subject. In 1703 he had gone with five important war vessels to prey upon the Dutch fishing vessels off the shores of Spitzenburg. In summer, in latitude 81° (the sun would be visible all day long), he was caught in a very dense fog and for nine days could not see the sun or form any idea of the time of day. He was using as timekeepers sand-glasses which had to be turned every 30 minutes. At the end of the nine days, when the sun appeared, their time was in error by 11 hours. The thing to note is that in 1703 on this important naval

[1] See *L'Horloger*, November, 1920.

expedition they did not take a single watch, but preferred the sand-glass. It must thus be assumed that the watch of the time was keeping worse time than a sand-glass. This would mean that watches were doing worse than an hour a day.

During the first half of the eighteenth century (1700 to 1750) came jewels and the modern escapements, and the accuracy must have been tremendously increased. We know the accuracy of Harrison's chronometer is 1761 (see Chapter XVI). This was a fourth attempt and represented the work of a lifetime. It was of course much more accurate than the watch of the time, and in addition was carefully tended during the trips. It throws an interesting light, however, on the accuracy at that time. On board the "Deptford" from Portsmouth to Port Royal, Nov. 18, 1761, to Jan. 18, 1762, and on board the "Merlin," from Jamaica to Portsmouth, Jan. 28, 1762, to April 2, 1762, the chronometer had changed but $1^m 5^s$. On board the "Tartar" to Barbados, March 28, 1764, to May 13, 1764, and on board the "New Elizabeth," from Barbados to Surrey Stairs, June 4, 1764, to July 18, 1764, it was found that, after allowing for the supposed rate of one second a day gaining, the chronometer had gained 54^s. This chronometer thus ran a little better than a half second a day — almost modern accuracy.

Collecting antique watches. — Antique watches are scarce and very valuable and for this reason most of them are in museums or the private collections of the rich or at least the very well-to-do.

No antique watch is a good timekeeper. An antique watch must thus be valued as a work of art and something from the past and not as an accurate timekeeper. For this reason comparatively little attention is paid to the condition of the movement in estimating the value of an antique watch. The case must be artistically pleasing and in good condition. Anything that is ugly, or of poor workmanship, or broken is thus of comparatively little value. This does not mean, of course, that no attention whatever is paid to

the condition of the movement. It is always more pleasing and valuable if the movement is in running order.

To determine the age of an antique watch is not always easy. Sometimes the watch is dated. The danger here is that the old date has been added later with fraudulent intent. Often the watch carries the name of the maker and this can be found in lists of makers and thus the approximate date determined. If of English make and not too old, the case may carry a hallmark. This letter will then give the age. If there is no date, name of maker, or hallmark, then the age must be determined by observing carefully the movement and case. In connection with the movement the things to note are the pillars, dial, hands, balance cock, escapement, fusee, and screws. In connection with the case, note the size, shape, method of decorating, form of pendant, and how the movement is fastened in the case. From these facts a fair idea of the age of a watch can usually be gained.

Many antique watches have been renovated, reconstructed, and changed. Sometimes parts of several watches have been built into one. Sometimes later improvements have been added. Anything like this detracts tremendously from the value of an old watch. And it must also unfortunately be added that changes have often been made in antique watches with fraudulent intent to deceive the unwary collector.

It is almost impossible to state the current price of antique watches. It depends so much upon the age, the fame of the maker, the condition of the watch, the jewels used in the case, and the like. A clock-watch in good condition with an iron movement dating from 1550 is worth from $700 to $1000. Others are worth from $200 to $10,000. Occasionally a collection is dispersed by private sale or auction. This is, of course, an unusual opportunity to secure antique clocks or watches and to form an idea of their value. Usually the same people who deal in antique clocks, deal in antique watches as well.[1]

[1] See page 171.

CHAPTER XIV

THE HISTORY AND CONSTRUCTION OF THE INDIVIDUAL PARTS OF WATCHES

This chapter is in a certain sense a supplement to Chapter VIII on the watch of to-day and to Chapter XIII on the history of watches from 1600 to 1800, for it contains additional facts and details. The material presented in these previous chapters will not be repeated here except occasionally and then only as a brief summary. These chapters should thus be fresh in mind.

For convenience it will be again assumed that a watch movement may be divided into four groups of parts, namely, the driving mechanism, the transmitting mechanism, the controlling mechanism, and the indicating mechanism.

The driving mechanism. — The driving power is supplied by a ribbon of steel called the mainspring, which is closely coiled in a circular metal box, free to rotate, and called the "going barrel." Every American watch to-day has a going barrel, but this is not true of all foreign watches and has not always been true of all American-made watches. Sometimes the barrel is stationary, in which case it is only a recess hollowed out in one of the plates which hold the movement. Then the main driving wheel must be fastened to the arbor and not to the barrel. Sometimes the barrel does not turn while the watch is running but is turned during winding. In all cases one end of the mainspring is fastened to the inside of the barrel and the other to the central arbor. Mainsprings vary in length, width, and thickness, depending upon the size of a watch. A ratchet and click must always be associated with a mainspring, so that it will not immediately uncoil as soon as wound up. The barrel turns once in eight hours, or three times during the twenty-four hours. The mainspring is usually made of

such a length that a watch will run forty hours before running down. In the earliest pocket watches the mainspring was so short that the watch usually ran but twelve or fifteen hours. It will be remembered that if a watch has twenty-three jewels, then the barrel arbor has hole jewels in which to run. If a watch has less than twenty-three jewels, then there are no jewels in the driving mechanism.

The use of a mainspring as the driving power was introduced by Peter Henlein of Nürnberg in 1500. It made the timekeeper portable and thus started the evolution destined to produce the pocket watch, but, from the very beginning, there was one difficulty which for centuries caused trouble. A mainspring when newly wound up pulls much harder than when nearly run down. When the old verge escapement was in use, this profoundly influenced the rate of running of the watch. The first invention to equalize this pull was the stackfreed, which was used from 1500 for perhaps half a century or more. This has been described and illustrated on page 125. The second invention for equalizing the pull was the fusee, which was devised by Jacob Zech of Prague in 1525. This has been described and illustrated on page 126. It is quite successful and is now used in all chronometers, a few foreign watches, and many accurate clocks. It was used in all good watches until 1800, or even later. It is now omitted as unnecessary because mainsprings are made of better steel; they are longer, so that only a portion of their action is used; escapements far less sensitive to changes in the driving power have replaced the old verge escapement; the hairspring has been introduced and is adjusted to isochronism. Tapering mainsprings have also been tried, but they were unsuccessful and soon abandoned.

There are three other things which are sometimes associated with the driving mechanism. These are stop work, maintaining power, and the up-and-down indicator. The purpose of stop work is to prevent overwinding and sometimes to make use of the middle portion of a spring which is too powerful when fully wound up. Such a spring

should of course never have been put in the watch. Several forms of stop work have been invented, but the one used in all watches which have stop work is called the star wheel, or the Maltese cross, or the Geneva stop. These various names indicate its origin and appearance. It has been fully described and illustrated on page 176 in connection with clocks. Stop work on watches is not common. Probably less than five per cent of the watches selling for $10 or more have stop work. Most of the best ones are without it.

The purpose of maintaining power is to keep the watch running as usual while it is being wound. During winding the power may be taken off the train to a considerable extent and thus a watch might lose a few fifths of a second. The double ratchet form of maintaining power invented by Harrison (1693–1776) is the one used on all watches which have it. It has been fully described and illustrated on page 175. Extremely few watches made to-day have maintaining power. With a going barrel it is unnecessary since the tension on the train is then greater during winding rather than less.

The up-and-down indicator is very convenient. On the dial is a little hand which moves over an arc and indicates how long ago the watch was wound up. The watch pictured in Fig. 72 has such an indicator. Several forms of the necessary mechanism for moving the hand have been invented during the last fifty years and are in use by different manufacturers. It is not extremely complicated and yet it requires quite a few parts.

The transmitting mechanism consists of a train of wheels and pinions for transmitting the power from the driving to the controlling mechanism. In the modern watch it consists of three arbors, each provided with a wheel and pinion. In the early pocket watches in 1600 there were but two. The first arbor turns in one hour, the next usually in $7\frac{1}{2}$ minutes, the next in one minute, and the escape wheel arbor in the controlling mechanism usually turns in six seconds. This would cause the balance to beat 18,000 times an hour. Sometimes the number of

beats is 21,600, 19,800, 17,280, 16,200, 15,400, or 14,000. It depends upon the maker and the size of the watch.

In the modern watch the arbors end in pivots which run in hole jewels. This has not always been the case, however. Jewels were first introduced by Facio (or Facie) in 1700 or a little later. Before that time the pivots simply ran in holes in the brass plates of the movement. The introduction of jewels added greatly to the timekeeping accuracy of watches, and the number used in watches has steadily increased. The maximum number is twenty-three.

The teeth of the wheels have radial sides and epicycloidal tips and the leaves of the pinions have radial sides and semicircular tips. The theory as to the shape of the teeth and leaves has been given on page 178 in connection with clocks.

It will be remembered that two of the arbors of the transmitting mechanism are brought forward through the dial and serve as the points of attachment of the hands.

The controlling mechanism is the most vital part of a watch and it is but natural that more improvements have been made here than anywhere else. In 1600 the pocket watch had a foliot balance, verge, and crown wheel as the controlling mechanism. During the three centuries from 1600 to the present time, three tremendous improvements have been made in the controlling mechanism. The balance has been improved, the hairspring has been introduced and improved, and the verge and crown wheel have been replaced by far better modern escapements. These three lines of improvement must now be considered.

The balance used in 1600 was plain and of one kind of material, usually steel. The balance of to-day consists of an inner rim of steel to which is fused a thicker outer rim of brass. The rim is cut through in two places near the arms of the balance and there are a number of screws which are inserted in the rim. A balance constructed in this way compensates for temperature changes both in itself and in the hairspring and can be adjusted to position. These are two very important things which could not be accomplished with the old balance. These modern balances have not

been in use very long. The first experiments began more than a century ago at the hands of Harrison, LeRoy, and Arnold, but the general introduction of these compensated balances into pocket watches took place less than forty years ago.

Although a balance wheel made of steel and brass is used in practically all American factory-made watches, this is not the case in most European-made watches of extreme precision. Here the so-called Guillaume balance is used. The steel has been replaced by an alloy of nickel and steel first introduced by Ch.-Éd. Guillaume in 1899. The temperature compensation is more perfect over a considerable range of temperature. Very recently (1920) so much progress has been made in the preparation of alloys, chiefly at the hands of Guillaume, that a perfectly plain, uncut alloy balance is being tried. Such a balance has decided advantages. It is more stable and is not so much affected by changes in the density of the air, that is, changes in the barometric pressure. The reason is because less air is carried along with the balance in its movements.

The balance spring, or hairspring, as it is often called, did not exist in the pocket watch of 1600. The balance was not controlled. Shortly after this time a straight hog's bristle was occasionally used in a watch to curb the motions of the balance. The balance spring was invented through the experiments of Hooke, Hautefeuille, and Huygens a few years before 1700. Since then it has been made longer, with more turns and of much better steel. Many balance springs are flat coils, but the outer end in most cases is brought up and over the rest of the coils, thus producing what is called an overcoil. This was invented by Abraham Louis Bréguet (1747–1823). It is claimed that there is less danger of the coils being caught in the regulator pins due to a sudden jar and that the adjustment to isochronism can be made a little easier and more perfectly. Springs of alloy and of other materials than steel have been experimented with.

Very recently (1920) a new alloy chiefly of nickel and

steel, introduced by the famous Ch.-Éd. Guillaume of Paris, and called "élinvar," gives great promise. It has all the advantages of steel and at the same time keeps its elasticity unchanged for a considerable range of temperatures. The hand of progress thus seems to be pointing towards a plain, uncut alloy balance wheel which shall be insensible

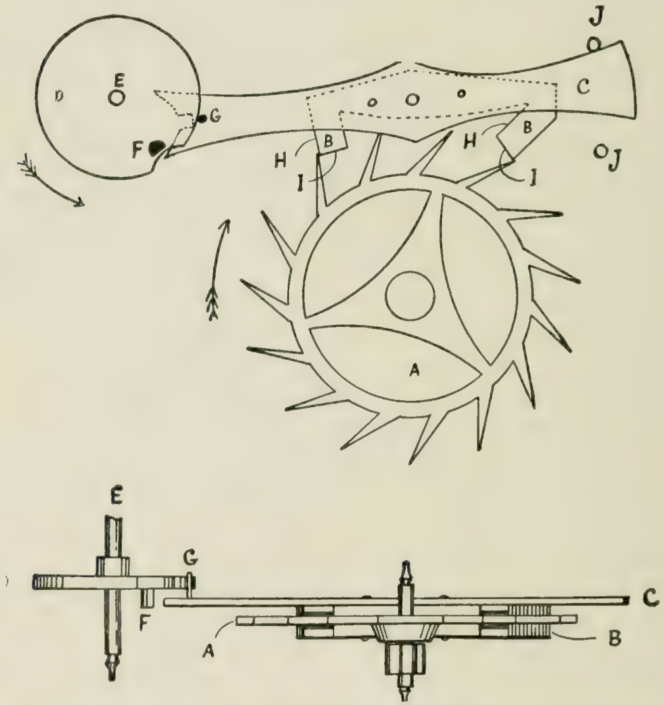


FIG. 174. — A DETACHED LEVER ESCAPEMENT OF THE RIGHT-ANGLED FORM.
(From GARRARD, *Watch Repairing.*)

to temperature changes and an alloy spring whose elasticity shall be independent of temperature as well.

The pocket watch of 1600 had a verge and crown wheel escapement which was very sensitive to changes in the pull of the mainspring and could not make a watch an accurate timekeeper. Between 1650 and 1700 experiments began to

be made looking to the introduction of a better escapement. From that time until the present day more than a hundred different escapements have been devised. To take up all these in detail would require a very large volume. Of all these, however, there are only four which have had any considerable use and have survived. These four are the cylinder escapement invented by Tompion in 1695 and improved by Graham in 1720; the duplex escapement invented by Dutertre in 1724 and improved by LeRoy in 1759; the detached lever escapement invented by Mudge in 1750; and the chronometer escapement invented by Pierre LeRoy in 1765 and perfected by Earnshaw and Arnold about 1780. And of these four the cylinder escapement and the duplex escapement, particularly the latter, are fast going out of use. The chronometer escapement is used in a few high-grade watches. These are often called pocket chronometers. It is primarily the escapement of the chronometer and will be treated in the chapter devoted to that timekeeper.

The detached lever escapement of the so-called straight line form is used in every American-made watch to-day and this was fully described and illustrated in Chapter VIII. Another form is much used in foreign watches, particularly English. This is illustrated in Fig. 174 and its action is essentially the same as that of the straight line form. It consists of an escape wheel *A* with 15 ratchet teeth; the lever *C*; and the roller *D* with the ruby pin at *F*. The two pallets are shown at *B* with locking faces *H* and impulse faces *I* and the two limiting banking pins are shown at *J*. This is a single roller escapement and the guard pin is shown at *G*. It will be seen that it has exactly the same parts as the straight line form.

A modern cylinder escapement is illustrated in Fig. 175, where both a horizontal and a vertical section are shown. The escape wheel *B* has fifteen very peculiar teeth. Each one is a little triangle supported by a short upright stem rising from the periphery of the escape wheel. The cylinder shown at *A* is hollow and made of steel. For a little distance nearly half of it has been cut away. The hair-

spring and balance (not shown) are of course attached to this cylinder. The size of the teeth and the cylinder must be very nicely adjusted to each other, for at times the cylinder is between two teeth of the escape wheel and at times a tooth is inside the cylinder. The action of the escapement can be traced out in the diagram. At *A* the cylinder is moving to the left (counterclockwise) and soon the point of the teeth will escape from the inside of the cylinder. As

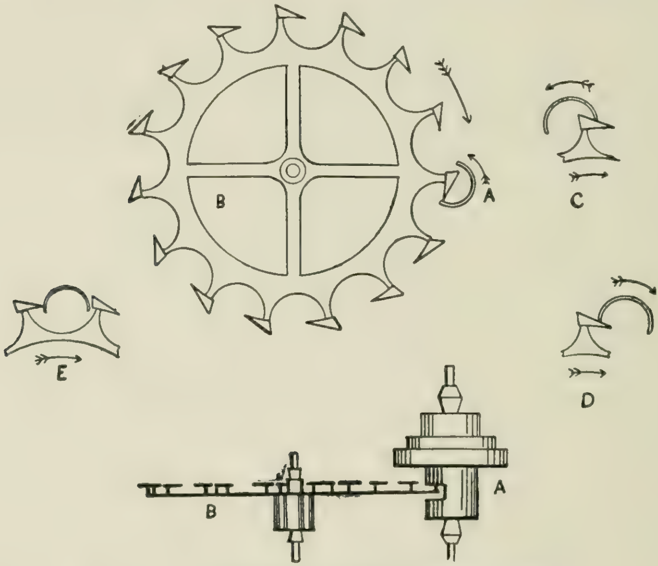


FIG. 175. — A MODERN CYLINDER ESCAPEMENT.
(From GARRARD, *Watch Repairing.*)

it escapes it will give the lip of the cylinder an impulse as at *C*. The escape wheel now moves forward until the point of the next tooth strikes the outside of the cylinder and is stopped. The cylinder will keep on turning until finally brought to rest by the hairspring. It will then commence its swing to the right (clockwise) and will eventually come into the position shown at *E*. As soon as it has gone a little farther the point of the tooth passes the lip of the cylinder and the tooth begins to escape as shown at *D*,

giving the cylinder an impulse. The point of the same tooth now falls on the inside of the cylinder and stops. The cylinder swings to the right until stopped by the hair-spring and then begins to return, thus coming into the position shown at *A* and completing the cycle of motions.

A modern duplex escapement is illustrated in Fig. 176, where both a horizontal and vertical section are shown. The escape wheel *A* has fifteen long pointed teeth *D* which are for locking and escaping and fifteen short upright teeth or pins *C* which are for giving the impulse. The balance staff for part of its length consists of a ruby roller *E* with a vertical groove in it. There is also attached to the balance staff a long arm with the pallet *B* for receiving the impulse. As shown in the diagram the ruby roller is moving to the left (counter-clockwise) and the long pointed tooth is about to escape from the groove. As soon as it passes out, the escape wheel begins to turn and as the short upright tooth strikes *B* it gives it an impulse. The escape wheel continues to rotate until the next long tooth strikes the outside of the ruby roller and is stopped. The ruby roller moves on to the left until stopped by the hairspring and then begins the return trip. During the whole of this return nothing happens except the long tooth falls into the groove in the ruby roller. In this escapement a tooth escapes

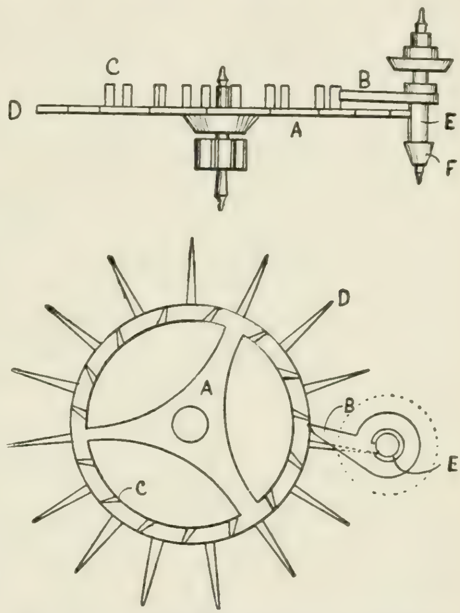


FIG. 176.—A MODERN DUPLEX ESCAPEMENT.
(From GARRARD, *Watch Repairing.*)

entirely and an impulse is given only during the swing to the left. No impulse is given or tooth escapes during the return vibration. It is called a duplex escapement on account of the double set of teeth.

Of the three escapements which have been described the detached lever is the best for good watches. The balance is entirely free from the escape wheel for most of its swing and is in connection with it only to unlock a tooth and receive an impulse. It is also an escapement which is very certain in its action. Oil must, however, be applied to the pallets and this in time thickens and affects the rate of running. The cylinder and duplex escapements are both frictional escapements. This means that some part of the escape wheel is in contact with the balance arbor or something connected with it all the while. A frictional escapement is somewhat less affected by inequalities in the force transmitted by the train than a detached escapement and this is an advantage. In a cylinder escapement oil must be applied to the inside of the cylinder and to the teeth of the escape wheel. In a duplex escapement oil must be applied to the ruby roller and to the point of the impulse pallet.

It is interesting to note in connection with these escapements that the cylinder, which was invented in England, found great favor in France and Switzerland and the duplex, which was invented in France, was more used in England.

The indicating mechanism consists of the hands and dial and the motion work or under-the-dial mechanism. The pocket watch of 1600 had only one hand, namely, the hour hand. The concentric minute hand came into general use about 1700 or a little later when jewels, better escapements, and the like, had much improved the accuracy of running. Previous to that time a few watches had been made with minute hands but they were often not concentric and furthermore, they represented only isolated examples by some famous watchmaker and not a general practice. The motion work came into existence when the concentric minute

hand made its appearance. It enables the hour hand to be driven by the minute hand and it also makes possible the easy setting of a watch. The second hand came still later, when the accuracy was further improved.

The dials of the early watches were made of brass, gold, or silver. They were often decorated with chasing and engraving. When enamel painting was at its height, the dials were also treated in this way. The plain white or bluish white enamel dial came into use about 1700. Until very modern times Roman numerals were used and the bottoms were towards the center, so that some of them were upside down. IIII is also almost always used for IV.

Dials are at present often spoken of as "double-sunk" or "triple-sunk" dials. In a triple-sunk dial, for example, the portion of the dial around the center is below the level of the rest of the dial and the portion around the second hand is still lower. The purpose of this is to allow a little more room so that there is less chance of the hands catching on each other or scraping the cover glass.

Tourbillon or Karrusel watches should perhaps receive a brief notice here. It is an arrangement of the train and escapement invented by Bréguet. The escapement is mounted in a light steel frame and revolves around the fourth wheel. The escapement thus comes into all positions and position errors are to a great extent eliminated. Bréguet's arrangement has been slightly modified by others since his time. But very few of these watches are manufactured and they are all foreign watches. In fact it is sometimes stated that they are so complicated that almost no one knows how to make them at present. It is an instance when in theory it seems like a wonderful invention, but in practice it is so complicated that more troubles are introduced than cured.

Keyless watches. — Stem winding and stem setting watches did not come into general use until fifty years ago or even later. Before that time it was necessary to open the case of a watch to set it or wind it up. This was done by means of a watch key and some of the early watch keys were things of beauty as well as use. They were quite

large and elaborately ornamented. In many museums collections of old watch keys will be found.

Keyless watches were occasionally made as early as before 1700, but they were always unique examples by some especially ingenious person. It was well past 1800 before various devices began to be patented to do away with the key and those used on modern watches are usually less than fifty years old.

The early keyless watches were not all stem winding watches in the modern sense. Sometimes they were wound by moving round a projection on the side of the watch. Sometimes the stem was pushed in and pulled out with a kind of pumping action. The credit for inventing the shifting sleeve keyless mechanism is usually given to Adrien Philippe in 1843. The rocking bar mechanism was patented by Gustavus Hughenin in 1855.

Watch pillars and balance cocks. — There are two other parts of a watch movement which in the past were much ornamented but are now plain and for use only. These are watch pillars and balance cocks.

Watch pillar is the name applied to the posts which hold the two plates of a watch movement together. At present they are simple cylindrical pieces of brass and can not be seen unless a movement is taken out of its case. In the early days of watches they could be seen when a hinged watch movement was lifted up to be wound. Then they were quite elaborately decorated and eight or ten well-known forms are recognized.

The balance cock is the projecting bar which holds one end of the balance arbor. This too in the early days of watches was made large and beautifully decorated. It was sometimes of brass, pierced, and heavily gilt. Sometimes an enamel painting was placed on it. At present in a watch movement they are no larger than necessary and never especially ornamented.

Clocks which are built like watches. — At the present time there are literally millions of clocks which are always called clocks and are clocks in the modern sense of the

term, but they are built exactly like watches. The cheap nickel alarm clock which sells at prices ranging from 50 cents to $3.00 belongs to this class. There are also many so-called French clocks or traveling clocks which are unusually good timekeepers and belong here. There are also many other styles and varieties.

It will be remembered that it was the invention of the mainspring in 1500 which produced the portable timekeeper. It was called the clock-watch and was spring-driven and balance controlled. This clock-watch developed in about a century into the pocket watch and into the so-called table clock. In 1658, when the pendulum was invented, it was immediately applied to all clocks, as the accuracy was so much increased. From 1658 on all *clocks* were pendulum clocks and practically the only balance controlled timekeepers were pocket *watches*. Thus during this whole period from 1658 to well past 1800, when factory methods began to be employed in making timekeepers, there were almost no spring-driven, balance-controlled clocks. The many improvements in watch mechanism caused this enormous modern production of clocks built like watches.

In the modern factory-made nickel alarm clock, the mainspring is not placed in a going barrel. One end is firmly fastened to a post attached to the plates which hold the movement. The other end is attached to the arbor. This is the winding arbor and it extends through the back of the clock and to it is attached the winding piece. The main driving wheel rides free on this arbor and is attached to it by means of the ratchet and click. In the time train the pinions are nearly always lantern pinions. The escapement is always some form of the detached lever escapement. The right-angled form is particularly common. Of course there are no jewels. The jewels in the escapement are replaced by steel and the arbors end in pivots which run in holes in the brass plates of the movement. If one does not understand from the pictures and description the construction of the watch there is no better way to learn it

than to take apart and study carefully a cheap alarm clock. And nearly every family possesses two or three which have been discarded.

The modern so-called French clock or traveling clock is usually well made. It often runs a week, sometimes strikes the hours, or is a repeater. The spring is generally contained in a going barrel and the pinions are solid with leaves. The escapement is very often the cylinder escapement and there are sometimes a few jewels. These clocks often have glass panels in the cases so that the movement can be seen and studied.

CHAPTER XV

THE ATTACHMENTS TO WATCHES AND COMPLICATED WATCHES

The more usual attachments to watches are the striking, chiming, alarm, repeater, chronograph, calendar, moon phase, and equation of time attachments. At present in modern watches the repeater, chronograph, and calendar attachments are the ones most desired; the moon phase and alarm attachments come next; the others have almost entirely gone out of use. In the case of antique watches, the striking, alarm, and calendar attachments were the most usual.

Some watches are unusual in the way the hours or minutes are indicated or in other ways.

Watches are sometimes very complicated, playing tunes at certain times, having automatic figures, or possessing a large number of the attachments.

This chapter is given over to the consideration of these attachments and unusual and complicated watches.

The striking, chiming, and alarm attachments. — Some watches strike the hours in regular course and thus differ entirely from repeaters which strike when a projecting slide is moved round or the pendant is pushed in. These are sometimes called clock-watches, although it would probably be better to keep that designation for those early sixteenth century watches which were really more like clocks than watches. This attachment was very common in the earliest watches but is almost never added to a watch made to-day. During the first century in the history of watches, from 1500 to 1600, probably more than half of the watches were striking watches, but the percentage has steadily decreased, and now there are almost none made. The mechanism used at present is always the rack and snail and very similar to the corresponding mechanism in a clock. There

are two trains and two mainsprings, but they may both be wound up by the same keyless winding mechanism turning forward to wind one spring and backward to wind the other. One thing should be held in mind. A watch comes into all positions so that gravity can not be depended upon to cause any part to *fall* into its proper place if released. Each part must have its spring to push it into the proper position when released. This is why one of these watches with attachments seems a mass of springs and levers to the uninitiated. A striking watch can be easily made a repeater. All that is needed is an arrangement so that pushing something outside will release the striking train inside. Of course, if a striking watch were repeated too often the striking part would run down before the time part. Briefly expressed, then, a striking watch contains on a small scale the rack and snail striking mechanism of a clock.

Some watches strike the quarters and even chime before the hours. The mechanism is very similar to that used in clocks for the same purpose.

There are also alarm watches and these again have practically the mechanism of an alarm clock.

What was said about the popularity of the striking attachment is also true concerning the chiming attachment. The alarm attachment is a little more desired than the other two. No one of them, however, is in any great favor. There are four reasons for this. In the first place, it is so much more expensive to have watches with attachments cleaned and repaired. Again, attachments nearly always cause a watch to keep poorer time and the great desire to-day is for an accurate timekeeper. In the third place, nickel alarm clocks have become so small and cheap, and, fourthly, a watch can hardly make noise enough to be easily heard unless careful attention is paid to it.

The repeater attachment is one of the most desired of all the attachments. When a projecting slide in the edge of the case is pushed round a short distance or the pendant is pushed down, the hour, quarter, etc., last indicated by the hands are struck on one or two gongs. This will be

repeated as often as the mechanism is started. There are hour repeaters, quarter repeaters, half-quarter repeaters, five-minute repeaters, and minute repeaters, the mechanism becoming more and more complicated with the exactness of the time indicated. In the hour repeater, the hours are struck on one gong. The other forms make use of two gongs. In the minute repeater, for example, the hour is struck on one gong, the quarter with quick double ting-tang blows on the two gongs, and the minute on the second gong.

Repeating watches were invented by Edward Barlow or Daniel Quare just before 1700. It was Barlow who invented the rack and snail striking mechanism for clocks in 1676, and with this mechanism clocks could be made to repeat easily. Both Barlow and Quare applied the mechanism to watches and applied for a patent. The British Government decided in favor of Quare in 1687. During the next century many repeating watches were made, but the number has decreased at present, as the whole tendency now is against watches with attachments. Nevertheless, it is at present one of the most desired of all the attachments.

The mechanism is quite complicated and not the same with all modern makers. The underlying principles are, however, the same. Repeaters are all built after the general plan of the rack and snail striking and chiming clock. The hour repeater is naturally the simplest and that will be described first. When the slide is moved round or the pendant is pushed down, the rack is released and its spring pushes it against the snail, which has twelve steps and is fastened to an arbor turning in twelve hours. A small secondary mainspring is also wound up and this supplies the power for the repeating action. This mainspring now returns the rack and, in so doing, strikes the correct number of blows on the gong. If the slide is again moved round, the hour is repeated. The quarter and five-minute repeaters require two snails with their appropriate racks. There is the hour snail as before and in addition a snail with either four or twelve steps fastened to an arbor turning in one hour. The minute repeater uses three snails. There is one for

the hour and one for the quarter and in addition there is a four-armed snail, each arm having fourteen steps fastened to the same arbor as the quarter snail. This is for striking the minutes in each quarter. There must of course be intercommunication between the various racks and snails, so that each will function in the proper order. Fig. 177 gives a view of the mechanism of a modern quarter repeater.

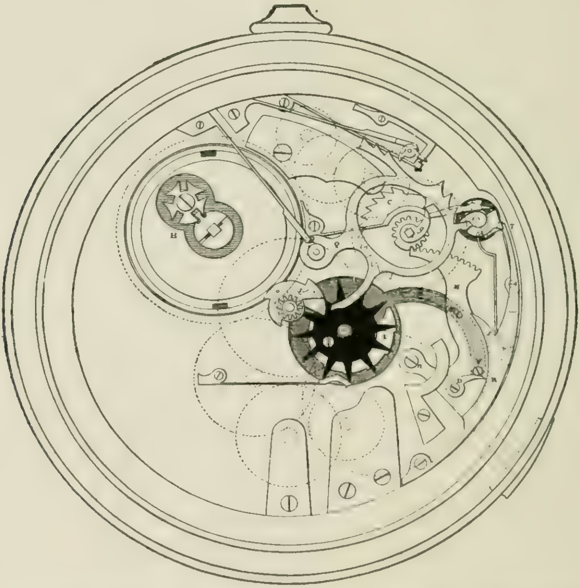


FIG. 177.—A MODERN QUARTER-HOUR REPEATING WATCH MOVEMENT.
(From SAUNIER, *Treatise on Modern Horology.*)

Most of the parts which have been mentioned can be made out. *L* is the hour snail and *l* the snail for the quarters.

The hours, quarters, etc., are actually struck by small steel hammers on circular wire gongs which run around the movement just inside the case. To regulate the speed of striking there is sometimes a striking train ending in a fly or even an escapement. There are also so-called "dumb" repeaters which really make no sound. There is only a

dull thud as the hammer strikes a steel block on the inside of the case.

The chronographic attachment and stop watches. — If a watch has a chronograph attachment there is a center-seconds hand which can be started, stopped, and then caused to fly back to zero by pressing the pendant or a knob on the rim of the watch case. The purpose of this attachment is to find the duration of some event. The center-seconds hand is attached to a wheel with a serrated or roughened edge which rides freely on the center arbor. This is driven by another wheel with serrated edge which is mounted on a pivoted arm or carriage, so that it can be moved enough to bring the two wheels into contact or to separate them entirely. This last wheel is usually driven by the fourth wheel of the time train. The vital part of the mechanism is what is sometimes called the "castle ratchet." This is a wheel with four, five, or six projections or castle teeth rising from its face and three times as many cogs on its edge. Every time the knob or pendant is pushed the castle ratchet is advanced one cog. The first push causes the driving wheel to be moved enough to come in contact with the wheel attached to the hand and the hand commences to move. The second push advances the castle ratchet one more cog and causes two things. The driving wheel is disengaged and a brake falls on the wheel attached to the hand, thus holding it firmly in place. The third push advances the castle ratchet one more cog and causes two things. The brake is removed and a lever with a pointed end is pushed by its spring against the heart-shaped cam, which is attached to the hand. This slides down the cam until it comes to the point nearest the center. The hand has thus been set back to zero. The cycle of operations is now complete and the next push starts the hand again. This mechanism is usually attached to the lower plate and is thus to be found directly underneath the dial.

A stop watch is a watch whose function is not to indicate the time of day but to do what the chronograph attachment does, namely, indicate the duration of an event. There are

two kinds of stop watches which, in the United States at any rate, are usually called the "foot ball timer" and "the split-second stop watch." In the foot ball timer the watch is started by pushing a projection at the side. It can be

FIG. 178. — A MODERN SPLIT-SECOND STOP WATCH.

stopped by pulling it back or pushing it the other way. It can be started again where it left off by pushing the projection forward once more. It is thus very convenient for "taking out time." It is set back to zero by pushing in the pendant. Such a watch differs little from an ordinary

watch. When it is stopped a little post is advanced until it comes in contact with the balance wheel and stops it. When it is started the post is moved back. The hands are set back to zero by means of the heart-shaped cam and pointed lever just as in the case of a chronograph attachment. The driving, transmitting and controlling mechanisms are just the same as in an ordinary watch.

The split-second stop watch usually has two hands which are together, one above the other. Sometimes they are of different materials or colors, so as to distinguish one from the other. This stop watch is operated exactly like the chronograph attachment. In fact it is simply the attachment amplified to become a complete watch. The first push of the pendant starts the hands, the second stops them, and the third causes them to fly back to zero. These watches must have the driving, transmitting, and controlling mechanisms of an ordinary watch in addition to the castle ratchet and its associated parts. One is illustrated in Fig. 178. The castle ratchet is located at the upper right-hand side of the movement. The levers which are actuated by it are all evident. The serrated wheel, which is moved up against the one which carries the hand, is seen at the bottom.

The purpose of two hands is this. There is a knob at the side of the watch and, when this is pressed, one hand stops. When it is pressed again this hand catches up instantly with the other. This enables the time of both "first" and "second" in any event to be taken with the same watch. It also enables the time of one lap to be determined without spoiling the record for the whole race. The mechanism for stopping one hand and then allowing it to catch up with the other is simple and yet quite delicate. It is pictured in Fig. 179. When the side knob is pressed, the two curved arms acting like a scissors catch the wheel attached to the hand and thus hold it fast. When the knob is pressed again, their hold on the wheel is released and the one hand catches up with the other through the operation of the heart cam and pointed lever which ordinarily hold the

two wheels together. Stop watches ordinarily have a small dial with a separate hand for indicating the number of complete minutes which have elapsed.

A foot ball timer costs from $4 to $15 and is not very delicate. A double split-second fly back stop watch costs from $10 to $60 and gets out of order quite easily. It should always be handled with great care.

Lending a stop watch to an inexperienced person is almost sure to be fatal. If a stop watch runs too fast or too slow, it may be regulated like an ordinary watch. To test

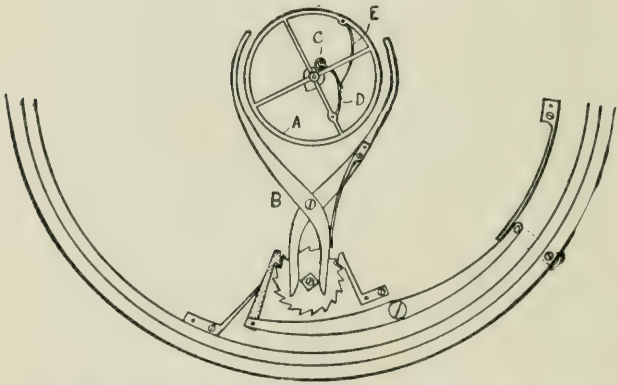


FIG. 179.—THE TWO HAND MECHANISM IN A DOUBLE SPLIT-SECOND STOP WATCH.

(From GARRARD, *Watch Repairing.*)

it, it should be allowed to run at least a half-hour and compared with some accurate timekeeper. In order to get the best results and avoid the errors of temperature, position, and isochronism, a stop watch should be held in the hand in the same position during a race as when tested. It should always be wound up completely before a race and wound up again if used more than two hours. A very bad practice in connection with a stop watch is to be continually starting, stopping, and setting it back to see if it works properly. This serves no useful purpose and is only a species of nervousness on the part of the user. It will be found that ex-

perience in using a stop watch to determine the duration of an event is fully as valuable as a good watch. As regards repairs, cleaning, and oiling, it should be treated like any ordinary watch.

Calendar, moon phase, and equation of time attachments. — Of these the calendar and moon phase attachments are among the most common. The equation of time attachment is, on the contrary, very seldom seen. The reason for this is because standard time has now become universal and also because modern life is no longer connected with the rising and setting of the sun and the time when it crosses the meridian. We no longer live sun-ordered lives. The calendar attachment was probably even more common in old watches than in modern ones. Some of the early watches, even those made before 1600, have this attachment.

FIG. 180. — THE DIAL OF A MODERN INEXPENSIVE MOON PHASE AND CALENDAR WATCH.

The mechanism for all these attachments is practically identical with the corresponding mechanism in clocks, only on a smaller scale. The necessary mechanism is usually attached to a separate plate which is fastened on over the motion work. It is thus to be found directly underneath the dial. In Fig. 180 is shown the dial of a modern inexpensive calendar and moon phase watch. Other modern moon phase and calendar watches are illustrated in Figs.

186 to 189. The watches illustrated in Figs. 186 and 187 have the equation of time attachment.

Unusual watches. — Watches are sometimes unusual in the way the hours and minutes are indicated. Such a watch is illustrated in Fig. 181.

The outer dial is fixed, and upon the semicircular arc at the top the minutes from 0 to 60 are engraved. Beneath this there is a semicircular slit through which the revolving lower dial can be seen. This turns once in two hours and contains two circular openings through which the hour numeral may be seen. Only one is seen at any one time. The other is covered by the fixed outer part of the dial. The minute is indicated by the position of the hour numeral. Thus in the figure it is 44 minutes past VI. As the time passes, the circular opening with the numeral 6 passes on to 60 and disappears. The other circular opening containing the numeral 7 now appears at 0 minutes and is visible during the next hour. This watch is by the famous Thomas Tompion, London, 1639–1713. It has a double silver case. The dial is of gilt metal. On the lower half is a miniature in black and white. The watch is $2\frac{1}{2}$ inches in diameter and is now in the Morgan collection.

Another method of indicating the hour and minute is occasionally met with in modern watches known sometimes as "jumpers." Here there are two rectangular openings in the dial. In one the hour appears and in the other the minute, as for example II 36. At the end of the minute this jumps almost instantaneously to II 37. At the end of the 60th minute the hour changes as well as the minute. Sometimes the hour only jumps and the minutes are indicated in the usual way.

Watches with peculiar ways of indicating the hours and minutes came into existence just before 1700. The incentive may have been the confusion caused by the introduction of the minute hand, which took place just before this time. This may have given rise to the desire for other methods of indicating the time than by using two concentric hands. Such watches (with the exception of the jumpers)

are practically never made at the present time. The whole tendency is away from anything unusual or complicated towards the simple, very accurate watch.

In connection with unusual watches mention should also be made of pendulum watches, musical watches, and traveling watches.

The so-called pendulum watch made its appearance just before 1700. The balance was placed just behind the dial and its arms were weighted. A slit in the dial permitted one of these weights to be seen. As the balance moved this appeared to move backward and forward very much like a pendulum. It was a very inconvenient arrangement, however, as it was too hard to get at the balance for purposes of regulation. Not many such watches were made and the idea was soon abandoned. One now in the Metropolitan Museum of Art in New York City is illustrated in Fig. 182. It was made by David Lestourgeon of London. It is in a silver case and is dated 1702.

Musical watches came in before 1800. They were made chiefly by the French and Swiss. Tunes were played either at pleasure or before the hours. These watches contain a rotating disc studded with pins which catch the free ends of steel springs. These springs are of a length and thickness to give the required note. A separate spring is necessary to drive the music disc. These watches are usually a little larger and thicker than an ordinary watch. Not many were made and they soon passed out of favor. Many had moving automatons in addition to being musical watches.

Traveling watches are simply watches of unusually large size. In diameter they vary from three to seven or eight inches. They were made almost from the time watches came into use until the advent of railroads. Some of them were complicated watches with attachments as well. One, nearly four inches in diameter, is pictured in Fig. 183. It was made by the famous Thomas Tompion in 1695.

Complicated watches. — A watch may be complicated in three ways. It may have moving automatons which

FIG. 181.—A WATCH WITH MOVING HOUR NUMERAL.

FIG. 182.—A PENDULUM WATCH, BY DAVID LESTOURGEON, DATE 1702.

FIG. 183.—A TRAVELING WATCH, NEARLY FOUR INCHES IN DIAMETER.

FIG. 184.—A WATCH WITH AUTOMATONS.

FIG. 185.—A COMPLICATED ASTRONOMICAL WATCH.

enact scenes and the like; it may have a very large number of the attachments which have just been described; it may be a so-called astronomical watch and show many things besides the time. A single example of a watch with moving automatons must suffice. Such a watch is illustrated in Fig. 184. It is of Swiss or German make and belongs to the eighteenth century. The face is of blue enamel with landscape and two mechanical figures hammering and grinding. They are moved by the mechanism of the watch. The dial is set in the blue sky of the landscape and is surrounded by diamonds. The watch is two inches in diameter, quite thin, and with a plain gold back. It is a part of the Morgan collection.

In Fig. 185 is pictured an astronomical watch by George Margetts. It carries the London hallmark of 1783. It indicates not only the time, but the tides, the moon's age, the place of the moon, the position of the sun, the sun's declination, the month, the date, and other things as well. The watch has pair cases, the inner of brass and the outer of gold. It is now in the Metropolitan Museum of Art in New York City, a part of the loan collection of Maurice M. Sternberger. George Margetts deserves to be ranked among the great watchmakers of his time because of the originality of his conceptions and the mechanical perfection of their execution. Complicated watches by him are also in the British Museum and in the Guildhall Museum in London. He also made chronometers and clocks as well as watches. He was admitted to the Clockmakers' Company in 1779, carried on business at 21 King Street, Cheapside, until about 1800, and then moved to No. 3 Cheapside. He died not long after 1806.

This chapter may well end with the description of four watches which are complicated because of the many attachments which have been added. In fact every attachment which exists will be found in connection with at least one and usually several of these four watches. They are modern watches and made by L. Leroy & Cie.; Paul Ditisheim; Patek, Philippe & Cie.; and Vacheron & Con-

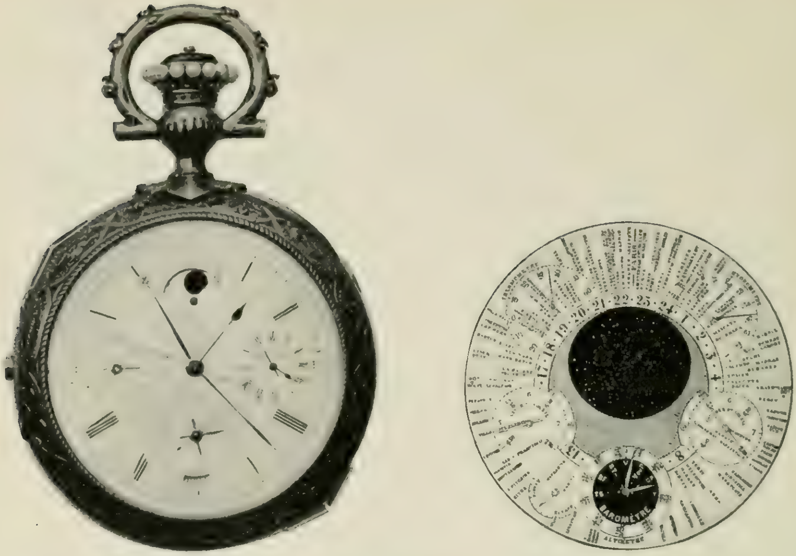


FIG. 186. — THE FRONT AND BACK DIALS OF A COMPLICATED WATCH, BY L. LEROY & CIE

FIG. 187. — DIAL AND MOVEMENT OF A COMPLICATED WATCH, BY PAUL DITISHEIM.

stantin.[1] They may be considered perhaps as the four most expensive and complicated modern watches in existence at the present time.

The watch by L. Leroy & Cie., of Paris and Besançon, is the most complicated ever constructed by them and probably the most complicated in the world. The front and back dials are shown in Fig. 186. In addition to indicating the time it has twenty-four other complications as follows:

1. Days of the week.
2. Date of the month.
3. Perpetual calendar of the months.
4. Dates (for 100 years).
5. Moon.
6. Seasons.
7. Sun time (apparent solar time).
8. Chronograph.
9. Minutes chronograph.
10. Hours chronograph.
11. Winding hand (up-and-down dial).
12. Full striking and silence.
13. Minutes repeater on 3 gongs.
14. Boreal sky, with the sidereal time and 460 stars.
15. Austral sky, with the sidereal time and 250 stars.
16. Local time of 125 towns.
17. Sunrise.
18. Sunset.
19. Thermometer.
20. Hygrometer.
21. Barometer.
22. Mountain barometer for 5000 meters.
23. Regulating system.
24. Compass.

This watch was presented to the International Jury of the Paris Exhibition of 1900 and is now owned by Royalty. The watch consists of 975 parts and was valued at the time of making at 20,000 francs. It has run well since its construction and has been cleaned but two or three times.

Fig. 187 shows both the dial and the movement (dial removed) of a very complicated watch by Paul Ditisheim of La Chaux-de-Fonds. This watch, in addition to the time, indicates the day of the week, the month, the date, and the phases of the moon; and the calendar is a perpetual one, for the watch automatically takes care of leap year. It also indicates the equation of time, and the time of the rising and of the setting of the sun.

[1] See Chapter XXII for more information about these firms.

FIG. 188. — A COMPLICATED WATCH, BY PATEK, PHILIPPE & CIE., OF GENEVA.

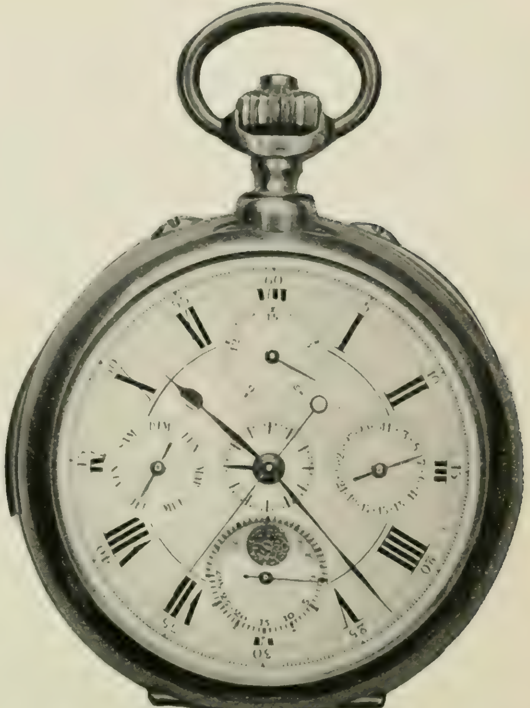


FIG. 189. — A COMPLICATED WATCH, BY VACHERON & CONSTANTIN, OF GENEVA.

The watch by Patek, Philippe & Cie. of Geneva was exhibited by them at the national Swiss exposition at Berne in 1914 and is now owned in the United States. It is pictured in Fig. 188. It is an open face watch in a gold case, weighing 215 grams, and having a diameter 56½ mm. At the time, the watch was valued at 12,500 francs (Swiss). In addition to indicating the time (hours, minutes, and seconds), it is a striking watch and also a striking repeater (quarters and minutes). It is a stop watch with two hands indicating the fifths of a second and also with a dial for showing the minutes and hours. It is also a calendar watch and shows the day of the week, the month, the date of the month, and the phases of the moon. There are three springs: one for the running of the watch, one for the striking mechanism, and one for the stop watch. It is thus in a sense three watches in one. There is also an up-and-down dial for showing the condition of each spring.

The complicated watch by Vacheron & Constantin of Geneva is pictured in Fig. 189. It is now in their museum in the salesroom at Geneva and may be seen there. Its size is 22 lines. Although a very complicated watch, it is also a watch of precision and holds a bulletin of the first class from the Observatory at Geneva. This watch is a striking repeater (quarters and minutes), and also an alarm watch. The small dial for setting the alarm may be seen in the center. It is a stop watch with dial for indicating the minutes and also a calendar watch, showing the day of the week, the month, the date, and the phases of the moon.

CHAPTER XVI

THE HISTORY, CONSTRUCTION, CARE, AND ACCURACY OF CHRONOMETERS

The word "chronometer" comes from two Greek words and means "time measurer." It could thus, as far as derivation is concerned, be applied to any timekeeper. As a matter of fact, it is only used for those very accurate, portable timekeepers of particular design, which are much used by astronomers and jewelers, and especially on shipboard to determine longitude.

The history of the chronometer and the history of navigation are closely linked together, for it was the great desire for methods of determining longitude in navigation which led to the invention of this particular kind of timekeeper. One of the earliest authors who touched upon navigation was John Werner of Nürnberg. In 1514 in his notes upon Ptolemy's Geography, he recommended the method of measuring the distance between the moon and stars in order to determine longitude. This later developed into the method by "lunar distances" and was for a long time the rival of the chronometer method of determining longitude. Only within recent times has it fallen out of use and left the chronometer method supreme. In fact this method led to the establishing of the Greenwich Observatory, for this observatory was founded first and foremost to get better positions of the moon and stars for use in navigation. The observatory was located in Greenwich Park, and Flamsteed was appointed the first astronomical observer March 4, 1675, at a salary of £100 a year. It was not until 1767 that the *Nautical Almanac* was founded by Maskelyne, a succeeding Astronomer Royal. This contained for the first time the distances of the moon from certain fixed

stars, so that the method of determining longitude by means of lunar distances could be applied at sea.

In 1530 R. Gemma Frisius wrote upon Astronomy, Cosmogony, and many kindred subjects. Watches had just been invented (1500) and were beginning to become known. He seized upon the idea of utilizing them to determine the longitude by comparing the local time with that of some standard meridian as kept by a watch. Watches were, however, far too inaccurate then to make this method a rival of the method by means of lunar distances. In fact as early as 1520 Alonzo de Santa-Cruz in his *de la Longitudinas* touched upon the same subject.

So great became the desire for better methods of determining longitude at sea, that in 1598 Philip III of Spain offered a reward of one hundred thousand crowns for a method of determining longitude with reasonable accuracy. The States-General of Holland followed shortly with an offer of ten thousand florins. When the pendulum was added to clocks just before 1700 and their accuracy was so much increased, experiments were tried in using them at sea instead of watches, but without success. In fact such famous men as Huygens and Hooke busied themselves with the problem and made experiments. Thus at the beginning of the eighteenth century the problem was still unsolved. The two rival methods were by means of lunar distances and by means of carrying a timekeeper, but neither method was satisfactory.

In 1714 in England a body called "commissioners for the discovery of longitude at sea" was formed. It had the power to grant annual sums to assist experiments and to reward discoveries with prizes. This body immediately offered prizes for a better method of determining longitude to be tested by a voyage to the West Indies and back; a prize of £10,000 was offered for a determination within 60 geographical miles, £15,000 if within 40 miles, and £20,000 if within 30 miles. Incidentally, it may be added that this body made its first grant in 1737, its last in 1815, although it existed until 1820. Its total disbursements

amounted to £101,000. The prize of £20,000 was won by John Harrison, often familiarly called Longitude Harrison, and it was the invention of the chronometer which constituted the improvement in determining longitude.

John Harrison (Fig. 190) was born at Foulby (Faulby or Wragby) near Pontefract, in Yorkshire in 1693. His father was a carpenter and perhaps repaired furniture and clocks as well as worked at his trade. In 1700 he removed to Barrow in Lincolnshire. John learned his father's trade, but showed very early a decided mechanical bent. When only twenty-two, he had already made a clock with wooden works. In 1726 he invented the gridiron pendulum to compensate temperature changes in clocks. Shortly after he also invented maintaining power and experimented with the compensating balance. These inventions have all been discussed in previous chapters. He was naturally attracted by the large prizes offered for better determinations of longitude at sea. In 1728 Harrison made what was probably his first trip to London, taking with him drawings of a proposed new timekeeper. These drawings were inspected by Graham, who urged him to actually make the timekeeper and then test its running. For seven years he worked on this timekeeper, in the meanwhile earning his living by repairing watches and clocks. In 1735 he removed to London and took up his residence in Orange Street, Red

FIG. 190. — JOHN HARRISON, 1693-1776.

Lion Square. He brought with him his new timepiece, which was a cumbersome affair, in a wooden frame, and had two balances. After its excellence of running had been tested, he was allowed for a final test to proceed to Lisbon. Its behavior was not sufficiently good to gain a prize, but he was given £500 to carry on further experiments. In 1739 he constructed a second timekeeper and then a third. Finally, in 1761, after more than twenty years of experimenting, when he was sixty-eight years old, he came before the Board of Longitude with a fourth timekeeper which he considered almost perfect. There was much delay, but finally permission was given to make the test, and, considering his age, his son William was allowed to make the trip in his stead. William sailed from Portsmouth on the "Deptford" on Nov. 18, 1761, and arrived at Port Royal sixty-one days later. He sailed from Jamaica on board the "Merlin" on Jan. 28, 1762, and arrived at Portsmouth April 2, 1762, after an absence of nearly five months. The chronometer, as we may now call it, although this name was introduced later, had changed but one minute and five seconds, which gives an error of only 18 miles in longitude, a value much within the prize limit of 30. Five thousand pounds were paid at once, but a second voyage as further proof was required. This was made to Barbados between March and July, 1764, and the chronometer again proved very satisfactory, in fact so satisfactory, that Harrison was declared the winner of the prize. Another £5000 was paid at once, but before getting the rest, Harrison was required to explain the construction of his chronometer. This he did in the presence of seven gentlemen, Aug. 22, 1765, and finally, after much delay, in 1769, or a little later, the other half of the reward was paid.

This same chronometer was tested at the Greenwich Observatory in 1766 for 298 days in different positions and at different temperatures. It did not do as well as at sea when it was carefully tended. Its greatest gain was 30^s when the temperature was $60°$ F. and the pendant was vertical and its greatest loss was 6.5^s when the tem-

perature was 32° F. and the chronometer was flat, dial up.

Harrison's successful chronometer is illustrated in Fig. 191. It was about four inches in diameter and had a large silver case. It had a fusee and was jeweled with rubies. The escapement is not the one now used in chronometers

Courtesy, Greenwich Observatory.

FIG. 191.—HARRISON'S SUCCESSFUL CHRONOMETER.

and, in fact, has fallen entirely out of use. It had a flat balance spring and a plain balance wheel. The influence of temperature changes was counteracted by means of what was called a "compensation curb." It consisted essentially of two strips of different metals, steel and brass, riveted together and so arranged that the effective length of the bal-

ance spring was changed as the temperature changed. This means that one end of the bimetallic strip was fastened to the plates of the chronometer and the other free end carried curb pins which embraced the balance spring. The chronometer was not hung in gimbals, but rested on a soft cushion when carried on the different voyages. Errors of position were avoided by carefully tending the chronometer and changing its position to suit the list of the vessel. The seconds were indicated on the dial by means of a center-seconds hand and not by a separate hand on a different portion of the dial as in the modern chronometer. All four of Harrison's chronometers are in the Greenwich Observatory and the drawings of his instruments are at the British Museum. Fig. 191, illustrating Harrison's successful chronometer, is due to the kindness of the Greenwich Observatory.

Harrison died on March 24, 1776, aged eighty-three years, and is buried in Hampstead churchyard. On his tomb is a long inscription setting forth his various achievements.

Although Harrison had won the £20,000 prize with his chronometer, it was by no means the chronometer of the present day. In fact the Board of Longitude immediately offered more prizes for improvements in the chronometer. It was nearly thirty years after Harrison's death before the timekeeper finally assumed its present form. The last century has seen practically no changes in construction. There are six men besides Harrison, some his contemporaries and some living a little later, who by their ideas, research, and inventions, have been chiefly instrumental in improving the chronometer. These are Pierre LeRoy, F. Berthoud, Bréguet, Mudge, J. Arnold, and Earnshaw.

Pierre LeRoy, the eldest son and successor of Julien LeRoy, was born in 1717 and died in 1785. To him we owe the invention, in principle at least, of the detent escapement which is now used in all chronometers. The date of this invention was about 1769, when Harrison was completing the tests of his prize chronometer. LeRoy in-

vented, or rather much improved, the duplex escapement for watches and is considered by some the greatest of French horologists.

Ferdinand Berthoud was born in Plancemont, in the canton of Neuchâtel, March 19, 1727. At an early age he became very fond of mechanics. In 1745 he came to Paris. One of the three works which he wrote is a treatise on marine chronometers. He died June 20, 1807. To him we are indebted for improvements in LeRoy's escapement. In Fig. 192 is illustrated one of his marine chronometers. It is No. 16, made in 1775 for the Royal Spanish Navy and now is the possession of Mr. Paul Ditisheim at La Chaux-de-Fonds. The striking thing, at first glance, is its size as compared with the modern chronometers.

Courtesy, Paul Ditisheim.

FIG. 192. — A MARINE CHRONOMETER, BY BERTHOUD, MADE IN 1775.

Abraham Louis Bréguet was born at Neuchâtel in Switzerland, Jan. 10, 1747. At the age of fifteen he began his apprenticeship in Paris. Later he became one of the most famous of French watch makers. He died Sept. 27, 1823. To him we owe chiefly experiments with the balance spring.

Thomas Mudge (Fig. 193) was born at Exeter in 1717, the son of a clergyman. He was apprenticed in 1729 to Graham, and on the death of the latter succeeded to the business. In 1765 he invented the detached lever escape-

ment for watches. He was made free of the Clockmakers' Company in 1738 and called to the livery in 1766. From this time, he turned his attention chiefly to the construction of chronometers. His first one was sent to the Greenwich Observatory in 1774. For this the Board of Longitude gave him £500 to carry on further experiments. He constructed other chronometers and finally was given £2500 for his work. His escapement was quite different from Harrison's but not like the modern chronometer escapement. In 1776 he was appointed watch maker to the king. He died Nov. 14, 1794.

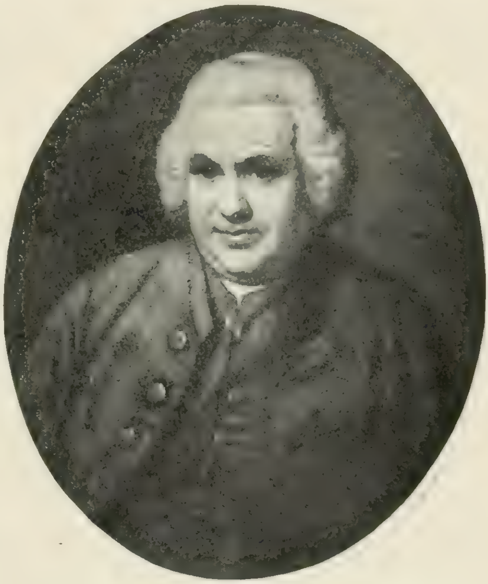


FIG. 193. — THOMAS MUDGE, 1717-1794.

John Arnold (Fig. 194) was born at Bodmin in Cornwall in 1736. He learned watchmaking of his father and after a short stay in Holland, came to London and here achieved great success. Soon he turned his attention to chronometers and finished his first one just before 1772. He invented the helical form of balance spring now always used. He improved the spring detent escapement invented in principle by LeRoy and improved by Berthoud. This he patented (No. 1328) in May, 1782. He also adopted the balance wheel of two metals. Furthermore, he introduced the name chronometer for this kind of timekeeper. He was also given £3000 for his investigations and inventions in connection with chronometers. He died at Well Hall, near Eltham, Kent, in 1799.

Thomas Earnshaw (Fig. 195) was born at Ashton-under-Lyne, in 1749. He began his apprenticeship at the age of fourteen and came to London as soon as it was finished. In 1781 he invented the spring detent escapement, slightly different from Arnold's, but precisely like that now used. He also devised the modern form of bimetallic balance wheel. He was also given £3000 by the Board of Longitude, but he always considered that too much credit had been given to Arnold and not enough to himself. He died at Chenies Street in 1829.

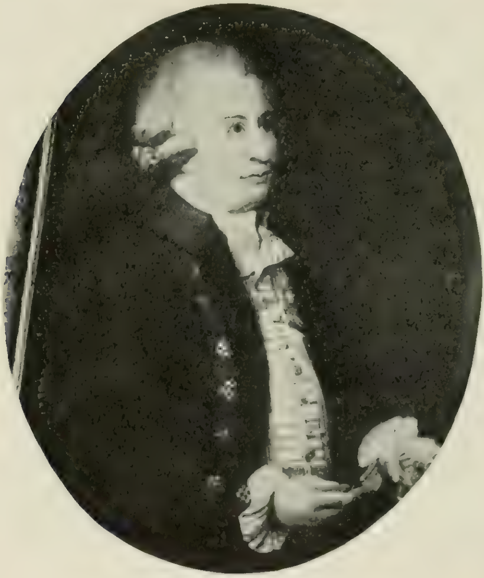


FIG. 194. — JOHN ARNOLD, 1736-1799.

Thus, at the beginning of the nineteenth century, due to the experiments and inventions of these six men in addition to Harrison, the chronometer in its modern form made its appearance. The last century has seen many attempts at improvement, but none of the additions or changes have stood the tests and received a general acceptance.

Very recently, within the last three or four years, changes have begun to be made in the chronometer chiefly at the hands of Paul Ditisheim of La Chaux-de-Fonds, which bid fair to be considered real improvements. These will be taken up a little later.

The construction of a chronometer. — A modern chronometer, like any other timekeeper, consists of four groups

of parts. These are the driving, the transmitting, the controlling, and the indicating mechanism.

The driving mechanism consists of a mainspring coiled inside of its barrel and connected by means of a flexible chain with the fusee for equalizing its pull. Every modern chronometer has maintaining power to keep the chronometer running while it is being wound, stop work to prevent overwinding, and a winding indicator (up-and-down dial) to show when it was last wound. All these things have been fully described elsewhere in connection with other timekeepers. A chronometer is usually constructed to run fifty-six hours, although to get the best results it should be wound regularly each day. If only a small portion of the long spring is used, the pull is much more uniform. The driving mechanism thus contains nothing new.

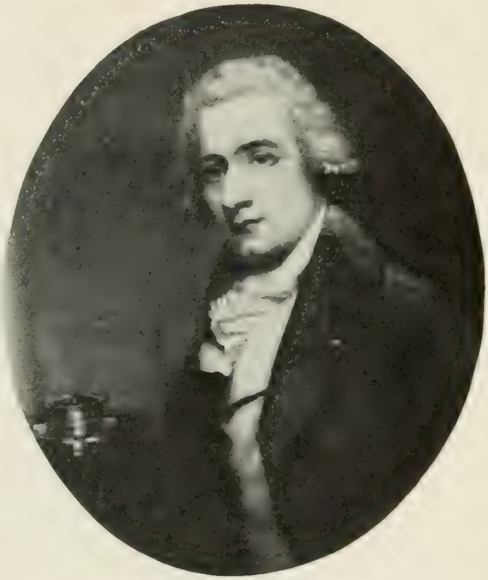


FIG. 195. — THOMAS EARNSHAW, 1749-1829.

The transmitting mechanism or time train is exactly like that of a watch and consists of three wheels and three pinions attached in pairs to three arbors which run in jeweled holes in the plates. The main driving wheel attached to the fusee and the pinion on the escape wheel arbor should perhaps be included. The four wheels in order usually have 90, 90, 80, and 80 teeth and the four pinions 14, 12, 10, and 10 leaves. The mechanism of a chronometer is illustrated in Fig. 196. One plate has been

removed and all of the controlling mechanism except the escape wheel. The mainspring barrel, the connecting chain, the fusee, and the wheels and pinions of the time train are all easily discernible.

It is in the controlling mechanism that a chronometer differs radically from a watch or clock, and we shall be introduced here to a new escapement. The controlling mechanism of a chronometer consists of escape wheel,

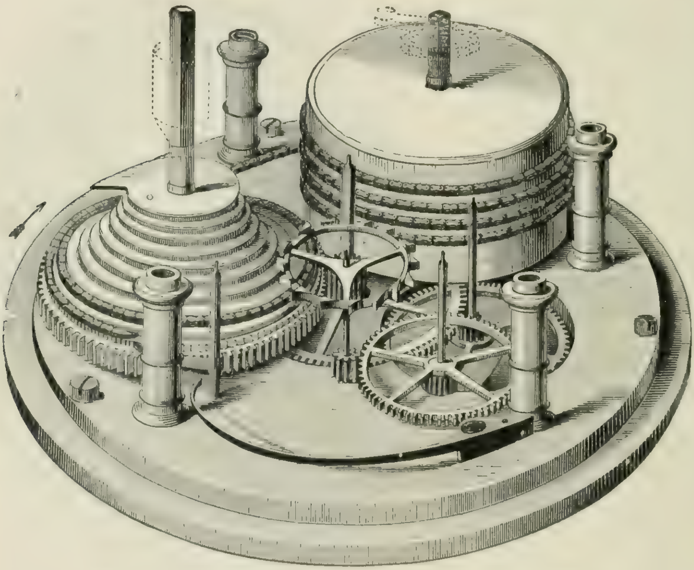


FIG. 196. — THE MECHANISM OF A CHRONOMETER.
(From BECKETT, *Clocks and Watches and Bells.*)

spring detent escapement (sometimes called the chronometer escapement), balance wheel and rollers, and helical balance spring. It will be remembered that the detent escapement was invented in principle by LeRoy, perfected by Berthoud and Arnold, and put into its modern form by Earnshaw. This escapement, together with the escape wheel *A*, are pictured in Fig. 197. It is the most detached of all escapements. The escape wheel is unlocked and an

impulse is received only during the swing in one direction. The return swing is independent of the escapement. It consists of the spring detent, the gold spring *D*, the locking pallet *C*, the impulse pallet *G*, the impulse roller, the discharging pallet *E*. As the discharging pallet *E* moves to the right (Fig. 197) it pushes the detent to the right until the tooth *H* of the escape wheel slips past the locking pallet at *C*. The escape wheel begins to turn in the direction of the arrow and the impulse pallet *G* is soon caught by a tooth *I*

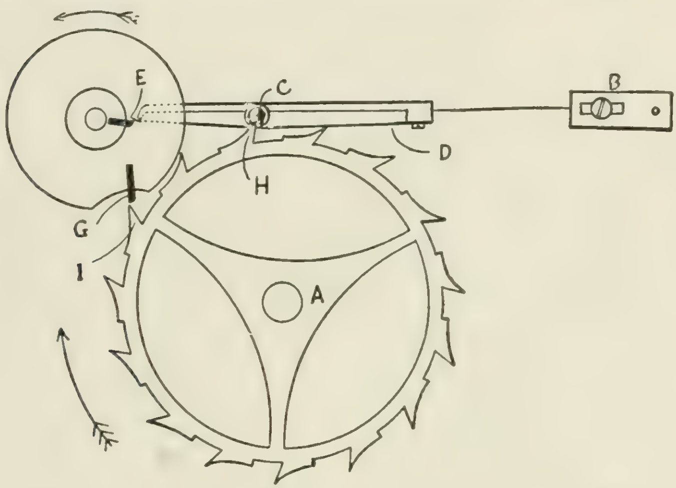


FIG. 197.—THE SPRING DETENT ESCAPEMENT OF A CHRONOMETER.
(From GARRARD, *Watch Repairing*.)

of the escape wheel and given an impulse. It continues to push on the impulse pallet and drive it ahead of it until the divergence of their paths separates them. In the meantime the discharging pallet *E* has passed beyond the spring detent and this has returned to its position of rest. The next tooth on the escape wheel now reaches the locking pallet *C* and the escape wheel is locked in position. The balance wheel and the two rollers carrying the impulse and discharging pallets now continue their excursion to the right entirely independent of the escapement. They are

finally brought to rest by the action of the balance spring and commence their return journey. When the discharging pallet comes to the detent, it flicks forward the gold spring *D* and passes on without disturbing the escapement. The discharging pallet must be of just the right length so as to come in contact with the gold spring only and not the end of the detent. The excursion to the left is made entirely independent of the escapement. The balance wheel and rollers are now again brought to rest by the balance spring and commence their motion to the right. During this part of the swing, a tooth of the escape wheel is discharged and an impulse is received. Thus a tooth of the escape wheel passes and an impulse is received during a swing of the balance wheel in one direction only and not in the other. The gold spring is so named because it is usually made of gold. The pallets are rubies or sapphires. This escapement is the most detached of any and without question the best. It is delicate, however, requires expert workmanship in its construction, and can be stopped by jars. It is ideal for chronometers and used in some watches which are called pocket chronometers or chronometer watches. It is not to be recommended for watches, however, unless the watch is very carefully used.

The balance is like the balance wheel of a watch and consists of an inner rim of steel and an outer rim of brass. It is cut through in two places and provided with screws for truing and for temperature adjustments. The balance spring is usually of the helical form and not flat. A wide thin wire in this form keeps its shape much better when subjected to jars or constant tremors. These helical springs are usually about half an inch in diameter and consist of about one quarter turn short of eleven, twelve, or thirteen turns.

The indicating mechanism consists of the hands and dial and the under-the-dial mechanism (motion work). There is nothing new in connection with this part of the mechanism.

The movement of a chronometer is usually placed in a cylindrical brass case, from two to five inches in diameter and

a little thicker than one half the diameter. This brass case is fastened in a wooden box by means of gimbals so that it will always remain level. Fig. 198 illustrates a marine chronometer complete. Gimbals are said to have been in-

FIG. 198. — A MARINE CHRONOMETER COMPLETE.

vented by Cardan (1501–1576) and first used by Huygens. The brass chronometer case is pivoted at two opposite points in a ring and the ring is pivoted at two points 90° from the others in the wooden box.

Good watches are carefully adjusted to position, isochronism, and temperature (see page 116). The same is true of chronometers except that position and isochronism errors are small and temperature must be very carefully looked out for. The use of gimbals causes the chronometer to always remain in one position, namely level. For this reason adjustments to position are less necessary than in a watch. The use of a long mainspring, sufficient to drive a chronometer fifty-six hours and a fusee to equalize its pull, make the errors of isochronism very small. Temperature compensation must, however, be very perfectly made. It has been found by experiment that a chronometer with an uncompensated balance, consisting of one metal only, will gain or lose about 6^s a day for a change of one degree Fahrenheit. A temperature change causes an expansion or contraction on the part of the balance wheel and balance spring and also a change in the elasticity of the balance spring. Marine chronometers with bimetallic balance rims are usually adjusted to be correct at about 45° and 90° (F.). This does not mean that they are correct below 45°, between 45° and 90°, or above 90°. In fact such a chronometer may readily be 2^s a day off halfway between 45° and 90°. This is sometimes called middle temperature error. So great is the desire to offset the influence of temperature on a chronometer that many forms of "secondary compensation" have been invented. These consist usually of little ingenious devices generally consisting of two metals which are attached to the balance wheel. Some twenty different forms have been devised and quite a few have been patented. If a chronometer is being very carefully adjusted before being placed in some prize competition, a secondary compensation device will ordinarily be used. In the rank and file of chronometers, however, they are not used.

Recent changes in the chronometer. — During the last few years changes have been introduced in the chronometer which seem to be along the road of progress and bid fair to be considered real improvements.

In the first place it is beginning to be a question if the

detent escapement is really better for a chronometer than a detached lever escapement. Opinion among experts is beginning to swing towards the detached lever. The chronometer is thus coming to be simply a big watch. The cut, bimetallic balance wheel and the helical balance spring are also being supplanted by alloy balances and flat alloy balance springs. Paul Ditisheim, of La Chaux-de-Fonds,

FIG. 199. — THE DIAL OF A NEW DITISHEIM CHRONOMETER.

for example, is experimenting with and introducing a solid, uncut alloy balance wheel with a little secondary compensation and a flat alloy balance spring whose elasticity is practically independent of temperature changes. There are two advantages. In the first place the temperature compensation is closer, and secondly the chronometer is not so much affected by changes in the density of the air, in other words, by changes in the barometric pressure.

There are four other improvements which have very recently been introduced by Mr. Paul Ditisheim, of La Chaux-de-Fonds. These are a new arrangement of the dial, a mechanism for setting a chronometer, an attached winding key, and a box to contain the balance and escapement. These are illustrated here through the kindness of Mr. Ditisheim.

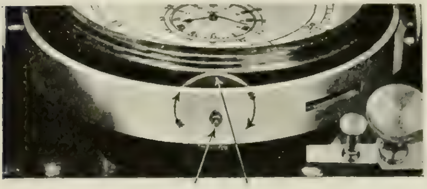


FIG. 200. — A MECHANISM FOR SETTING A CHRONOMETER.

In the new arrangement of the dial (Fig. 199) the hour and minute hands move over a small portion of it and the second hand is pivoted in the center and moves over the whole dial. The great advantage of this new arrangement is apparent at the first glance to anyone who has used a chronometer for comparing timekeepers, for making eye-and-ear observations in Astronomy, or for sextant observations. The seconds may be divided into halves, or quarters, or fifths.

The outside portion of the mechanism for setting a chronometer is shown in Fig. 200. By pressing and turning, the hour and minute hands may be set at will. This is a great convenience as compared with unscrewing the dial cover and using the key.

FIG. 201. — A PERMANENTLY ATTACHED WINDING KEY.

Fig. 201 illustrates the permanently attached winding key. The advantages are that the key is never mislaid and dust is excluded.

The balance wheel and escapement are inclosed in a small circular box, as shown in Fig. 202. The great advantage is that dust is excluded and the chronometer needs

cleaning and oiling much less often. It also offers another possibility. Small windows could be placed in the side of the box. An aneroid barometer box might be included in the chronometer, which by its movements might open and close the windows and thus compensate for the influence of changes in barometric pressure.

The care of a chronometer. — Since a chronometer is intended to be the most accurate possible portable timekeeper, many things must be considered in its handling and care, in order to get the best results. Some of these will now be taken up.

All chronometers are wound by means of a key. There is a small circular hole in the bottom of the brass case which is covered by a dust cap held in place by a spring. In winding a chronometer it should be turned slowly and carefully nearly halfway over. The dust cap is then pulled up and the key inserted. The square hole in the key fits over the squared arbor of the fusee. A few very modern chronometers may have the new attached winding key or knob. In winding a chronometer the necessary number of half turns of the key should be known, so that the last one may be made very slowly and carefully. There is, to be sure, a winding stop to prevent overwinding, but it does a chronometer no good to come up against the stop with a hard blow. The chronometer key has a ratchet in the handle, so that if by mistake the key should be turned backward, this ratchet would work and thus undue pressure would not be put on the time train. A chronometer should be wound regularly at the same time each day. The best results are obtained when exactly the same amount of expansion of the mainspring is used each day. After winding, some advocate turning the chronometer slowly entirely up-

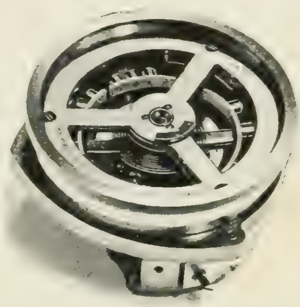


FIG. 202. — AN INCLOSED BALANCE WHEEL AND ESCAPEMENT.

side down, so that the dial is down, and then completing the revolution as it comes back into its normal position. The theory is that this redistributes the oil on the pivots in the best manner possible.

A chronometer is also set by means of the key. The same square hole fits over the squared end of the arbor of the center wheel in the middle of the dial. A chronometer should be set just as little as possible, for the pressure of the key and the strain on the time train in setting may change the rate of running. If the hands are to be set forward, it should be done slowly and steadily. It is usually said that a chronometer should not be set back. It seems a lot of trouble, however, to set a chronometer ahead nearly twelve hours when one may wish to set it back a few minutes. If it is set back, it should be given one quick turn, thus setting it back more than the desired amount. It may then be set slowly forward to the time desired. A jeweler ordinarily takes the movement out of the case and then stops the balance wheel with a soft brush the desired amount. It is better for an inexperienced person not to try this, however. There is no good method of setting the second hand except by stopping the chronometer. To push the second hand with a knife blade, for example, is "chronometer murder."

A chronometer should always be kept in the same place. The hanging of a chronometer in gimbals causes it to be level and it has been adjusted primarily to this position. To get the best results, a chronometer should not be kept in different places even if it is always level and the moving is done without jar or harm.

A chronometer should be jarred as little as possible. Violent shocks are, of course, to be avoided because they might cause it to gain or lose a little or even stop the chronometer. Slight jars and tremors are also to be avoided as much as possible. On shipboard a chronometer should not be placed so as to feel the vibrations of the engines any more than is necessary.

Magnetic influences should be avoided as much as

possible. A chronometer should never be placed near a dynamo or compass and if it is necessary to transport one, it is better not to do it on an electric car. It is not particularly sensitive, however, — no more so than a watch.

A chronometer should be kept as free from dust as possible. Its case is very tight, for the bezel ring which holds the cover-glass over the dial is screwed on and the winding hole has a dust cap. Nevertheless, a chronometer should not be needlessly exposed to dust. The disadvantage is that it makes more frequent cleaning and oiling necessary.

The rate of running of a chronometer is also affected by changes in the barometric pressure (i.e., the density of the air), by changes in the moisture content of the air, and by changes in temperature. The last is by far the most important. The first two are almost negligible. It is usually not possible to control the surroundings of a chronometer, but if it is, then the pressure, moisture, and temperature, particularly the last, should be kept as constant as possible.

A chronometer must from time to time be cleaned and oiled, and occasionally it will need repairs. It goes without saying that it should be intrusted only to a skilled jeweler and one who has had experience with chronometers. The oil used must be the best. It must change its consistency as little as possible with changes of temperature. It must have no chemical action on any of the metal parts of the chronometer. It must not deteriorate or change on exposure to the air. How often a chronometer should be cleaned and oiled is a question to which a definite answer cannot be given. Some would say every two years and some might even say once in seven years is often enough. It depends somewhat upon the care which a chronometer has had.

As regards the care of chronometers at sea, article 260 from Bowditch: *American Practical Navigator* may be quoted. This book, so familiar to every navigator, may be considered as practically the one standard book on navigation in English.

Care of Chronometers on Shipboard. — The box in which the chronometers are kept should have a permanent place as near as practicable to the center of motion of the ship, and where it will be free from excessive shocks and jars, such as those that arise from the engines or from the firing of heavy guns; the location should be one free from sudden and extreme changes of temperature, and as far removed as possible from masses of vertical iron. The box should contain a separate compartment for each chronometer, and each compartment should be lined with baize cloth padded with curled hair, for the double purpose of reducing shocks and equalizing the temperature within. An outer cover of baize cloth should be provided for the box, and this should be changed and dried out frequently in damp weather. The chronometers should be placed with the XII mark in the same position.

For transportation for short distances by hand, an instrument should be rigidly clamped in its gimbals, for if left free to swing, its performance may be deranged by the violent oscillations that are imparted to it.

For transportation for a considerable distance as by express, the chronometer should be allowed to run down, and should then be dismounted and the balance corked.

The "Deutsche Seewarte" at Hamburg gives these rules for sending chronometers long distances: (1) The chronometer should first be allowed to completely run down. (2) Fasten the balance wheel by pushing small cork wedges or strips of paper under it. If cork is used, it must be new, free from dust, and from acid. This should be done by a skilled jeweler, as the chronometer must be taken out of its case and the wedges put under in just the right place. The escape wheel may also be tied fast. (3) The gimbals must now be firmly fastened. (4) The space between the chronometer case and the wooden box must be filled with dry, dust-free soft material. (5) The wooden box must now be closed and packed in a large box or basket with plenty of soft material around it.

The manufacture of chronometers. — For fifty years or more after Harrison made his fourth chronometer and with it won the great prize of £20,000 in 1762, chronometers continued to be made individually and entirely by hand.

Nearly every watch or clockmaker of repute also made chronometers. In fact every maker of timekeepers made watches, clocks, or chronometers as his inclination led him or his customers desired. Each timekeeper received individual attention and was probably a little different from any other. It is only during the last fifty years that certain firms or individuals have specialized in making chronometers and factory methods have to a certain extent been introduced.

In the United States at present the three firms deserving special mention are:

William Bond & Son, 22 Beacon St., Boston, Mass.
John Bliss & Co., 128 Front St., New York City.
T. S. & J. D. Negus, 140 Water St., New York City.

Of these William Bond & Son is the oldest firm, as the business was established in 1793. They have made between five hundred and one thousand chronometers to date. John Bliss & Co. come next in age. The business was founded by John Bliss's father at 40 Fulton Street in 1835. The firm has had several slightly different firm names and moved to 128 Front Street in 1880. The firm of T. S. & J. D. Negus was founded in 1848 at 100 Wall Street. In 1869 the present building at 140 Water Street was occupied. The fourth generation is now active in the firm. Bliss has made between three and four thousand chronometers and Negus between two and three thousand. Thus the total American product is about seven thousand chronometers.

In England the following firms are particularly well known as chronometer makers:

E. Dent & Co., Ltd., 61 Strand, London.
Chas. Frodsham & Co., Ltd., 27 South Molton St., London, W. 1.
V. Kullberg, 105 Liverpool Road, London, N.
Mercer & Co., St. Albans, Hertfordshire, England.
Usher & Cole, 339 St. John St., London, E. C.

Mercer & Co. manufacture on a larger scale than the rest and make more use of factory methods. They also make all the parts of a chronometer themselves. This is not always true of other chronometer makers.

In France L. Leroy & Cie., Boulevard de la Madeleine, Paris, has a worldwide reputation.

In Switzerland among the particularly fine chronometer makers are:

Paul Ditisheim, La Chaux-de-Fonds.

Longines, Saint-Imier.

Nardin, Le Locle.

Vacheron & Constantin, Geneva.

In Germany among the most important manufacturers of chronometers are:

Chronometer-Werke in Hamburg.

L. Jensen.

A. Kittel.

A. Lange & Söhne in Glashütte.

F. Lidecke in Geestemunde.

C. Wiegand in Peine.

Many of these foreign makers of chronometers make high grade watches and perhaps precision clocks as well. For this reason more will be said about them in the chapter on European watchmakers.

The cost of a chronometer varies from perhaps $50 for a fair second-hand one to $500 or more for the best that money can buy. Ditisheim's new improved chronometers are selling (1921) for 2000 francs (Swiss) or a little less. Most of the firms issue catalogues describing their chronometers and giving the price.

The testing of chronometers and their accuracy.— Testing a chronometer and determining its accuracy means determining its error and rate under different conditions. By error is meant how much a chronometer is fast or slow. When slow the error is usually considered plus (+); when fast, minus (−). If the error is too large, it may be reduced by setting the chronometer, but it will be remembered that this should be done as little as possible. By rate is meant the amount that a chronometer loses or gains per day. It is considered plus if losing and minus if gaining. If the rate is too large it may be made smaller by "regulating" the chronometer. This means turning the timing

screws in the rim of the balance wheel, and it should, of course, be done only by a skilled person. The record of a chronometer consists of the values of error from time to time and the rates computed from them. It is the constancy of the rate which is the test of the accuracy of a chronometer.

The accompanying table contains the record of a chronometer for a year. This chronometer was made by one of the best English firms, but is a fairly old one — about fifty years old. It has no secondary compensation. It remained the whole time in the same place on a shelf in a physical laboratory. It received the best of care, but no attempt was made to control pressure, moisture, or temperature. The temperature varied irregularly from 55° to 85° F. during the period. It had been cleaned, oiled, and slightly repaired by a skillful jeweler a few weeks before the record begins. The errors were obtained by comparison with the noon time signal from Washington. The method of computing the rates is evident. For example, the error on March 24, 1917, was 12.0^s fast; on March 26 it was 16.5^s fast. This means a gain of 4.5^s in two days, or at the rate of 2.25^s per day. Since it is gaining the rate is recorded as -2.25^s. On inspecting the different values of rate, it will be seen that there is a steady change with the time. The chronometer started off by gaining more than two seconds per day. After a few months it had dropped to about 0.3^s or 0.4^s per day. It will also be seen that for a period of a couple of months the chronometer maintained the same rate within a few tenths of a second per day and this is just about what can be expected of an average chronometer which has good care, but when pressure, moisture, and temperature changes are not taken account of. A first class chronometer with secondary compensation would, of course, do somewhat better; that means that its rate would be a little more constant. If the error and thus the rate had been determined each day instead of every nine or ten days, the discrepancies in the rates would of course have been several times larger.

Stress should be laid upon one thing. To obtain correct values of the error of a chronometer or any timekeeper, absolutely correct time must be available. This is only true of the time obtained by observing the stars at some astronomical observatory or of the noon time signal. It is better not to take a chronometer to the telegraph office to make the comparison, but to use some secondary "hack" chronometer or watch and to compare it with both the chronometer and the noon time signal.

Date	Error	Rate
Mar. 24, 1917	12.0^s Fast	
26	16.5^s Fast	-2.25^s
30	26.0^s Fast	-2.12^s
April 4	34.0^s Fast	-1.80^s
9	42.5^s Fast	-1.70^s
21	$1^m\ 1.0^s$ Fast	-1.54^s
27	$1^m\ 4.0^s$ Fast	-0.50^s
May 5	$1^m\ 6.0^s$ Fast	-0.25^s
10	$1^m\ 8.0^s$ Fast	-0.40^s
17	$1^m 12.0^s$ Fast	-0.57^s
24	$1^m 20.0^s$ Fast	-1.14^s
June 1	$1^m 29.5^s$ Fast	-1.18^s
8	$1^m 33.0^s$ Fast	-0.50^s
12	$1^m 35.0^s$ Fast	-0.50^s
16	$1^m 35.6^s$ Fast	-0.15^s
23	$1^m 37.0^s$ Fast	-0.20^s
July 10	$1^m 45.5^s$ Fast	-0.46^s
24	$1^m 53.5^s$ Fast	-0.57^s
Aug. 6	$1^m 57.0^s$ Fast	-0.27^s
25	$2^m\ 1.0^s$ Fast	-0.21^s
Sept. 6	$2^m\ 5.0^s$ Fast	-0.33^s

Date	Error	Rate
Sept. 19	$2^m\ 8.5^s$ Fast	-0.27^s
Oct. 2	$2^m 15.0^s$ Fast	-0.50^s
18	$2^m 21.0^s$ Fast	-0.37^s
30	$2^m 23.0^s$ Fast	-0.17^s
Nov. 6	$2^m 26.0^s$ Fast	-0.43^s
13	$2^m 28.0^s$ Fast	-0.29^s
20	$2^m 32.0^s$ Fast	-0.57^s
27	$2^m 33.0^s$ Fast	-0.14^s
Dec. 7	$2^m 40.0^s$ Fast	-0.70^s
17	$2^m 45.0^s$ Fast	-0.50^s
26	$2^m 47.0^s$ Fast	-0.22^s
Jan. 2, 1918	$2^m 41.0^s$ Fast	$+0.86^s$*
8	$2^m 42.0^s$ Fast	-0.17^s
19	$2^m 46.0^s$ Fast	-0.36^s
24	$2^m 47.5^s$ Fast	-0.30^s
Feb. 2	$2^m 49.0^s$ Fast	-0.18^s
6	$2^m 48.5^s$ Fast	$+0.12^s$
15	$2^m 51.0^s$ Fast	-0.28^s
28	$2^m 52.0^s$ Fast	-0.08^s
Mar. 9	$2^m 52.5^s$ Fast	-0.06^s
16	$2^m 53.5^s$ Fast	-0.14^s

* A temperature about 30° F. lower was maintained for several days.

The rate of a chronometer is influenced by five things, namely: (1) Tremors, (2) changes in moisture, (3) changes in barometric pressure, (4) time, and (5) changes in temperature. These have been arranged in order of importance, the last being the most important. Time affects the rate because, as time passes, the oil thickens and changes its composition, dust collects, and the springs change their elasticity. Time is usually reckoned from the last time it was cleaned, oiled, or repaired. The first three influences

are always disregarded. They are very small and irregular. If quite a little time has elapsed (several months) since a chronometer was last cleaned and oiled, then the time factor also becomes a small one. This would leave temperature only to be taken account of. It is assumed, of course, in stating that those five things influence the rate of a chronometer, that the chronometer is receiving the best of care and is not being abused. To expose it to a strong magnetic field would, of course, affect the rate, but that would be abusing a chronometer.

For most first class chronometers, the temperature coefficient, as it is called, is determined. The chronometer formula takes this form:

$$R = R_0 + a(t - t_0),$$

where R is the rate for any temperature t, R_0 is the rate for the temperature t_0, and a is the temperature coefficient. t_0 is usually taken at about 70° F. and R_0 is determined by observing the chronometer for a considerable time at this temperature. a is then determined by exposing the chronometer to different temperatures and determining the corresponding rates. With R_0, a, and t_0 known, then the probable rate R can be computed for an observed temperature t. One without doubt gets the most out of a first rate chronometer by using it in this way and taking account of temperature changes. A better way of determining R_0 and a is to observe the value of rate R for a number of days at different temperatures. Each of these sets of observations would yield an equation containing the two unknowns R_0 and a. A "least squares" solution of these equations would give the best values for R_0 and a.

A much longer chronometer formula involving the time and further influences of temperature is sometimes used. The formula is:

$$R = R_0 + a(t - t_0) + b(t - t_0)^2 + c(T - T_0) + d(T - T_0)^2 + e(t - t_0)(T - T_0).$$

Here R_0 is the rate at time T_0 and temperature t_0, while R

is the rate at time T and temperature t. The constants R_0, a, b, c, d, and e must be determined by experiment. Such an investigation would be carried out only as a piece of research work in connection with an extremely good chronometer.

It will be seen that investigating a chronometer requires considerable skill, an accurate source of time, and the facilities of a laboratory. For this reason there is in nearly every country an observatory where the chronometers are tested for the navy and other places under more or less of government control where any chronometer that is admitted is investigated for a stated fee.

In the United States the chronometers for the navy are investigated at the United States Naval Observatory at Washington, D. C., and any chronometer may be sent to the Bureau of Standards, Washington, D. C., for testing. A pamphlet is issued by this bureau stating the time of the test, the fee, and all particulars. It is entitled, *Circular of the Bureau of Standards, No. 51, Measurement of Time and Test of Timepieces*. The cost of the pamphlet is 15 cents. A brief account of the testing of chronometers and torpedo-boat watches for the navy is found in the *Annual Report of the Naval Observatory*. For example, in 1916, the tests began January 15 and ended June 26. Forty-four new American, nine new foreign, and fifty-one old chronometers were submitted for tests. Of these thirty-three American, nine new foreign and thirty-two old chronometers passed. Of these the American chronometers were all made by Bliss, Bond, or Negus, and the foreign ones by Leroy or Nardin.

In England the chronometers are investigated for the navy at the Royal Observatory, Greenwich. The Greenwich observations for each year contain the results of the tests. Any chronometer may be sent by any one for tests to the National Physical Laboratory at Teddington, near London. Formerly (before 1913) the testing was carried out at the Kew Observatory, Richmond, Surrey. About one hundred are submitted each year.

In France the French navy (these are before-the-war

facts) buys its chronometers according to its needs of French manufacturers at the close of tests which take place each year from November 1 to March 31 at the "Service Hydrographique de la Marine," 13 Rue de l'Université, Paris. The price is fixed at 2100 francs. A prize of 1200 francs is given in addition to the chronometer ranked first each year. The tests include one for isochronism, one when the chronometer is tipped 22°, and four for temperatures between 0° and 30° centigrade. These figures and arrangements were the ones before the war. At present (1922) chronometers cost 3000 francs or more and no prize is offered. Any chronometer may be submitted to the Observatoire de Besançon for tests. A *Bulletin Chronométrique* is issued each year. Five or six on the average are submitted each year.

In Switzerland any chronometer may be sent for tests to the observatory at Neuchâtel or to the observatory at Geneva. Annual reports are published. About fifty or sixty are submitted annually at Neuchâtel and one or two at Geneva.

In Germany the chronometers are investigated for the navy at Kiel and Williamshaven. Any chronometer may be sent for tests to the Deutsche Seewarte at Hamburg. The annual report is published in *Ann. Hydrog.* The thirty-seventh competition, which took place in 1913–1914, is described in Vol. 42. Sixty-five chronometers were submitted and of these 48 were classified as first, 13 as second, 2 as third, and 2 dropped out of the tests. In 1917–1918, seventy-six were submitted and in 1918–1919, eighty-four.

The method of ranking the chronometers in all these tests depends upon empirical formulæ which are somewhat different in different places and contain the various values of rate under different conditions. For further details about these observatories where tests are made, see Chapter XXIV.

As a single illustration the procedure at the Neuchâtel Observatory may be cited. The tests for a marine chro-

nometer of the first class last 63 days and consist of 9 periods of 7 days each at the following temperatures: 32°, 25°, 18°, 11°, 4°, 11°, 18°, 25°, 32° C. The tests for a marine chronometer of the second class last 35 days and consist of 5 periods of 7 days each at the following temperatures: 32°, 18°, 4°, 18°, 32° C. To obtain a bulletin six conditions must be fulfilled. The formula for computing relative merit is:

$$A = \frac{100}{eE + cC + dD + rR}$$

where $e = 40$, $c = 33.3$, $d = 5$, and $r = 5$, and E is the average departure of the daily rate, C is the temperature coefficient, D is the mean error of compensation, and R is the return to previous rate. Supplementary tests for a wider range of temperatures, in a magnetic field, and under different pressures may be had if desired. If the chronometer has a contact maker, the errors of registration may also be tested.

CHAPTER XVII

THE HISTORY, CONSTRUCTION, AND CARE OF TOWER CLOCKS

Tower or turret clock is the name generally given to those large-sized clocks which are located in towers or turrets and have large detached dials often four in number facing in four directions and sometimes at a considerable distance from the works of the clock. Belfry clock is another name for them. They are also called church clocks and public clocks; church clocks because the steeple of a church is so often their place of location; public clocks because they are frequently located on public buildings and also because they render such a public service.

The history of tower clocks covers a long time, but there are not many events to be recorded. Some of the very first mechanical timekeepers were tower clocks. It will be remembered that clock mechanism began to make its appearance about the year 1000. It may have been a little earlier; more likely later. The clock may have been invented as a whole; more likely it was a gradual development. The tower clock has thus been known for perhaps a thousand years. The clock constructed by Henry de Vick in 1360 for Charles V of France and now located on the Palais de Justice is the first clock of which we know the construction and which was surely a mechanical clock in the modern sense of the term. This was a tower clock. All other clocks known to exist before that time have been mentioned in Chapter IV. Many of them would be considered tower clocks, although in every case there was but one dial and some may have had no dial at all. Until almost 1400 it is questionable if there was space in church towers for dials and hands. The early clocks all had bells on which the hours were struck. Such clocks thus an-

nounced the hours long before they had hands and dials to indicate the passing time.

From the fourteenth century to the present day the tower clock has never fallen out of favor. In fact the number has steadily increased until to-day there is hardly a city or town in any civilized portion of the world which does not possess what is often familiarly and even affectionately called "the town clock."

The changes in the mechanism of tower clocks kept pace with the changes in clocks in general. When the pendulum was invented in 1658 and added to other clocks it was added to tower clocks as well and greatly increased their accuracy. Better escapements were also used. At present the double three-legged gravity escapement invented by E. B. Denison in 1851 is more used than any other in good tower clocks. Its rival is the anchor escapement usually of the dead-beat type.

In the United States the first tower clocks appeared about 1700. The first one mentioned in that admirable volume *The Old Clock Book*, by N. Hudson Moore, is a church clock at Ipswich, Mass. The new Meeting House was built in 1699 and had a turret for the bell. In 1704 a clock with a dial was added. In 1735 the Third Parish Meeting House in Newbury, Mass., procured a tower clock. In 1740 the Meeting House in New Haven had a new bell and clock. The clock had brass works and was constructed by Ebenezer Parmilee. In 1740 the Reformed Nether Dutch Church of Schenectady had a bell and clock. In 1745 the first tower clock in Norwich, Conn., was placed in the Meeting House. The list is probably far from complete but there were very few tower clocks in the colonies before 1750.

The construction of modern tower clocks is not always exactly the same. The size makes some difference and there are also differences due to the fact that they are made by different firms. Again it depends upon what the clock is required to do. Occasionally they indicate the time only. Usually it is indicated on four dials, sometimes on only one,

two, or three. Almost always the hours are struck on a bell. Sometimes there are chimes at the quarters and before the hours. This of course requires a number of bells. The construction also depends upon the space available for the clock and upon the distance of the dials and bells from the works. However, the construction of tower clocks is so nearly the same that a description of one will give a fair idea of all.

The following description will apply to a clock with four dials about 7 feet in diameter located about 70 feet above the ground, which strikes the hours and has chimes. It will be assumed that the works are fairly near, say, on the floor below the dials and bells. It will also be the construction actually used by one of the best makers of tower clocks in the United States. It is thus the actual construction of an average well-made tower clock that is being described.

A horizontal frame (see Figs. 204, 205, and 206) is ordinarily used for holding the works. This arrangement was introduced by French tower clock makers somewhat before 1850 and has since become universal. The frame for the clock under consideration would be a heavy rectangular iron frame about six feet long and three feet wide and supported by four heavy legs at the corners about three feet above the floor. The various parts of the clock movement are fastened underneath, attached to, and placed above this frame. The mechanism is usually divided into three distinct portions. In the center is placed the timekeeping mechanism; at the right the mechanism for operating the chimes; at the left the necessary mechanism for striking the hours. Each will occupy about one third of the available space.

The timekeeping portion of the clock movement consists of the usual four groups of parts. There is the driving mechanism, the transmitting mechanism, the controlling mechanism, and the indicating mechanism. The driving mechanism consists of a heavy weight attached to a wire rope which is wound around the drum. The drum is about two feet long, more than a foot in diameter, and sufficiently

strong to withstand crushing. The weight must have sufficient fall to keep the clock running eight days, and be sufficiently heavy to drive it in all kinds of weather. It is far better if the wire rope, when the clock is completely wound up, forms but one layer on the drum. There is less force lost in friction if the weight can hang directly from the drum. This is very seldom possible, however, and usually the wire rope is led off to the side of the tower by at least two pulleys. In time the wire rope is sure to wear out and break. There should thus be some arrangement to avoid danger and damage when the weight drops. A box of broken stone or sand can perhaps be kept at the place where the weight will strike. As the weight is necessarily heavy, it is usually wound up by means of a windlass, and an intermediate winding gear is introduced to lessen the effort in winding. The time required is of course increased. There must be maintaining power, as it will require perhaps fifteen minutes or more to wind the clock and there should be some stop or automatic signal to tell when the weight is nearly wound up. The weight is sometimes boxed in and if this is the case the boxing must be sufficiently large so that if the wood becomes damp and swells it will not pinch the weight.

There is nothing new about the transmitting mechansim except the size of the wheels, pinions, and arbors which is necessary in order to transmit so much power.

The controlling mechanism consists of a double three-legged gravity escapement and pendulum and these are illustrated in Fig. 203. A gravity escapement is one in which the impulse is given to the pendulum by a weight falling through a constant distance. It consists of two arms, A_1 and A_2, which are hinged at the top, near the bending point of the pendulum spring. They end at the bottom in beat pins of brass or ivory which rest against the pendulum. At B_1 and B_2 are located the locking blocks. One is in front and the other at the back. In the center is the double three-legged affair which gives the name to the escapement. These two pieces are firmly fastened (squared

on) to the last arbor of the time train and take the place of the escape wheel. Two of the legs are lettered C_1 and C_2. Between them are three pins which at times push the arms A_1 and A_2 through the two projections from the arms E_1 and E_2. As the pendulum moves to the right it carries the arm A_2 with it and eventually pushes the locking block B_2 from under the leg C_2. The double three-legged escape wheel now revolves until the leg C_1 is locked on the block B. The pendulum continues its excursion to the right, carrying the arm A_2 with it until it finally comes to rest and starts the return trip to the left. The arm A_2 follows the pendulum down, giving it an impulse until it is eventually stopped by the projection E_2 coming in contact with a pin. As the pendulum goes on to the left it eventually pushes the locking block B_1 from under the leg C_1 and the three-legged escape wheel again revolves until another leg is locked on the block B_2. In revolving the pin pushing against E_2 has raised the arm A_2 a short distance. The fact that the arm A_2 is carried up by the pendulum a shorter distance than the arm follows it down explains the source of the impulse to the pendulum. The great advantage of this escapement is that it is entirely independent of the amount of power on the train. Possibly the hands are so loaded with ice and snow and the oil has so thickened due to cold that the weight is barely driving the clock. The impulse given the pendulum each time is just the same. Perhaps the wind is pushing the hands forward so that there is a great excess of power on

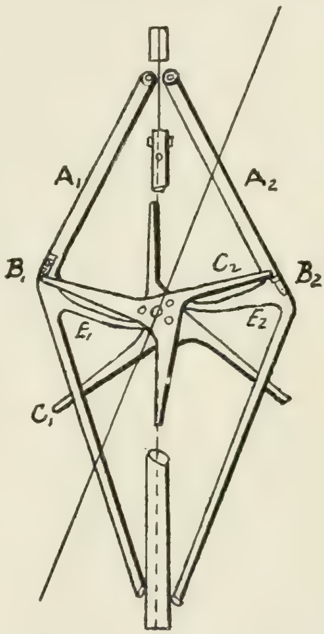


FIG. 203.—A DOUBLE THREE-LEGGED GRAVITY ESCAPEMENT.

the clock. The impulse still remains exactly the same. A fan-fly is always attached to the escape wheel arbor so that the legs will not strike the locking blocks with too great force. The pendulum should be compensated for temperature. Usually an iron zinc tubular pendulum rod is used, and the pendulum is made of such length as to swing in $1\frac{1}{2}$ seconds. Sometimes the rod is of wood, in which case it usually swings in one second. Sometimes a mercury compensation pendulum is used. The pendulum is generally attached to an A-shaped piece, fastened to the frame, and swings in front of it. If the floor upon which the clock stands is not very rigid, it is better to support the pendulum by a bracket fastened firmly to the wall of the tower.

The indicating mechanism is usually fairly simple. A rod with a universal joint and turning in one hour leads away from the clock to that part of the tower where the hands and dials are located. Here it sets in motion four rods leading to the center of the four dials. Just behind each dial is a typical under-the-dial mechanism (motion work) for driving the hour hand from the minute hand. There are fairly definite rules for the size of dials. The diameter of the dial should be about one tenth of its height above the ground. The figures and minutes together ought to occupy about one third of the radius of the dial. It has been found that gilt hands and figures on a black background or black hands and figures on a light background show up best. The dial may be made of copper, any sheet metal, wood, stone, or cement. If to be illuminated at night, opalescent glass is ordinarily used. In all these cases the dial is solid. Sometimes the bells are placed just behind the dials. If this is the case, then the figures and minute marks are carried on iron rings and there is nothing but lattice work behind the hands. This is necessary in order not to confine the sound of the bells. The hands should be as light as possible consistent with strength. They are sometimes made of wood. Usually they are hollow metal tubes, reinforced frequently by internal diaphragms. Solid metal hands would be too heavy. The hands are usually

counterpoised and the counterpoises are painted the same color as the dial, so that they are scarcely visible from the ground.

The striking mechanism makes up about a third of the clock mechanism and is generally located at the left of the timekeeping portion. The rack and snail striking mechanism is preferred to the count wheel. The snail is placed on an arbor in the time train, which turns once in twelve hours, and there is also a cam placed on an arbor turning in an hour, which raises a lever and allows it to fall exactly at the hour. This is the only connection between the timekeeping portion and the striking portion of the clock mechanism. The power for the striking mechanism is supplied by a heavy weight — heavier than the one required for timekeeping. This drives a train which ends in a fan-fly, which must be of sufficient size to make the strokes of the hour slow and regular. When the striking mechanism is in operation, projections on the great wheel, attached to the drum, pull the wire, which raises the hammer and delivers the blow to the bell.

The necessary mechanism for the chimes is placed at the right of the timekeeping portion. This is very much like the striking mechanism. A four-armed cam placed on an arbor in the time train, turning in an hour, raises a lever and lets it fall at the end of each quarter and just before the hour. This starts the chimes. The power is supplied by a large weight as before and there is also a train ending in a fan-fly. The actual striking is done by means of a chime-barrel. This is cylinder-shaped, like a barrel or drum, with projections on its surface. As this revolves it pulls the proper wires in order and delivers the blows to the bells.

The four figures, 204 to 207 inclusive, illustrate much that has just been stated. In Fig. 204 is illustrated the movement of a tower clock for time only as made by the Seth Thomas Clock Co. of Thomaston, Conn. It is 45 inches wide, 41 inches deep, and 76 inches high. It has a three-legged gravity escapement and an iron-zinc, tubular, compensated pendulum. It is suitable for four dials, 18

feet in diameter or less. The pendulum weighs 550 pounds and the whole movement 2800 pounds. In Fig. 205 is

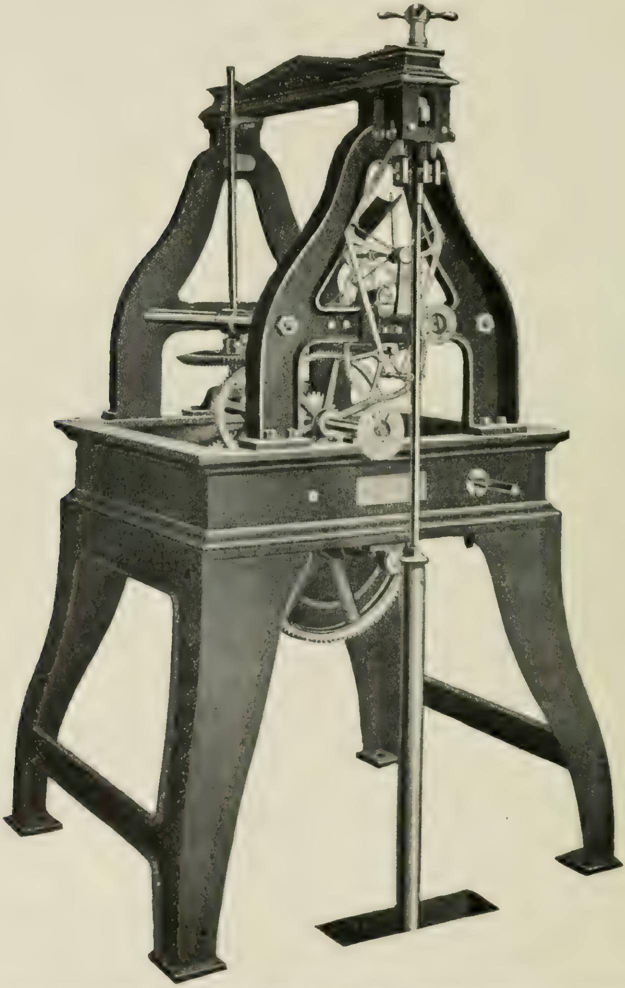


FIG. 204. — A TOWER CLOCK MOVEMENT, BY THE SETH THOMAS CLOCK CO.

shown a striking and chiming tower clock movement, also by the Seth Thomas Clock Co. This has an anchor escape-

ment and a wooden rod pendulum. The fan-flys for the striking part on the left and the chiming part on the right are plainly visible. It is 98 inches wide, 39 inches deep, and

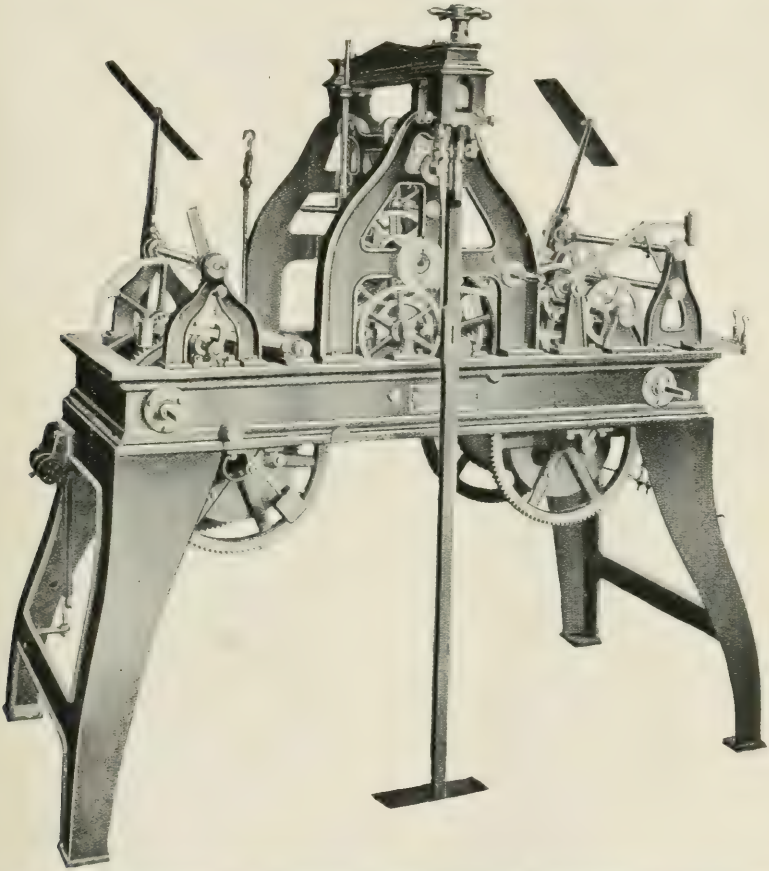


FIG. 205. — A STRIKING AND CHIMING TOWER CLOCK MOVEMENT, BY THE SETH THOMAS CLOCK CO.

72 inches high, and weighs 3800 pounds. The movement of a striking and chiming tower clock, as made by the E. Howard Clock Co., 373 Washington St., Boston, Mass., is pictured in Fig. 206. The striking mechanism is on the

right and the chiming mechanism on the left. The pendulum (not shown) is at the back. This is a powerful clock, capable of driving the hands on four dials, as large as 25 feet in diameter, and bring out the full tone of a bell as large as 10,000 pounds in weight. In Fig. 207 is shown a possible arrangement of a clock movement showing the time on four dials and striking the hours. There are many

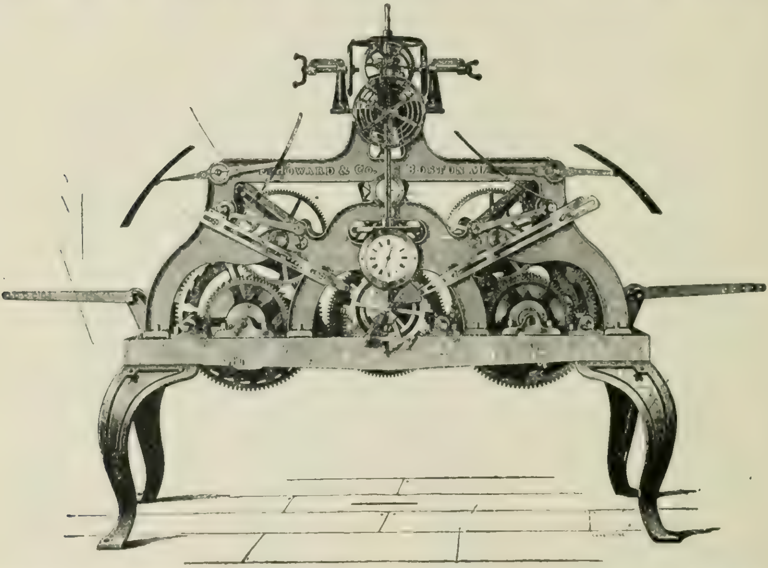


FIG. 206. — A STRIKING AND CHIMING TOWER CLOCK MOVEMENT AS MADE BY THE E. HOWARD CLOCK CO.

other ways of arranging the clock movement, dials, and bell in a tower.

The following specifications for a tower clock of this kind and size may be of interest. They are slightly modified from similar specifications given in Edmund Beckett's *Clocks and Watches and Bells*, and Ferson's *The Tower Clock and How to Make It*.

1. To make and place a clock with four dials —— feet in diameter, striking the hours and Westminster quarters on five bells, which would be the second, third, fourth, sev-

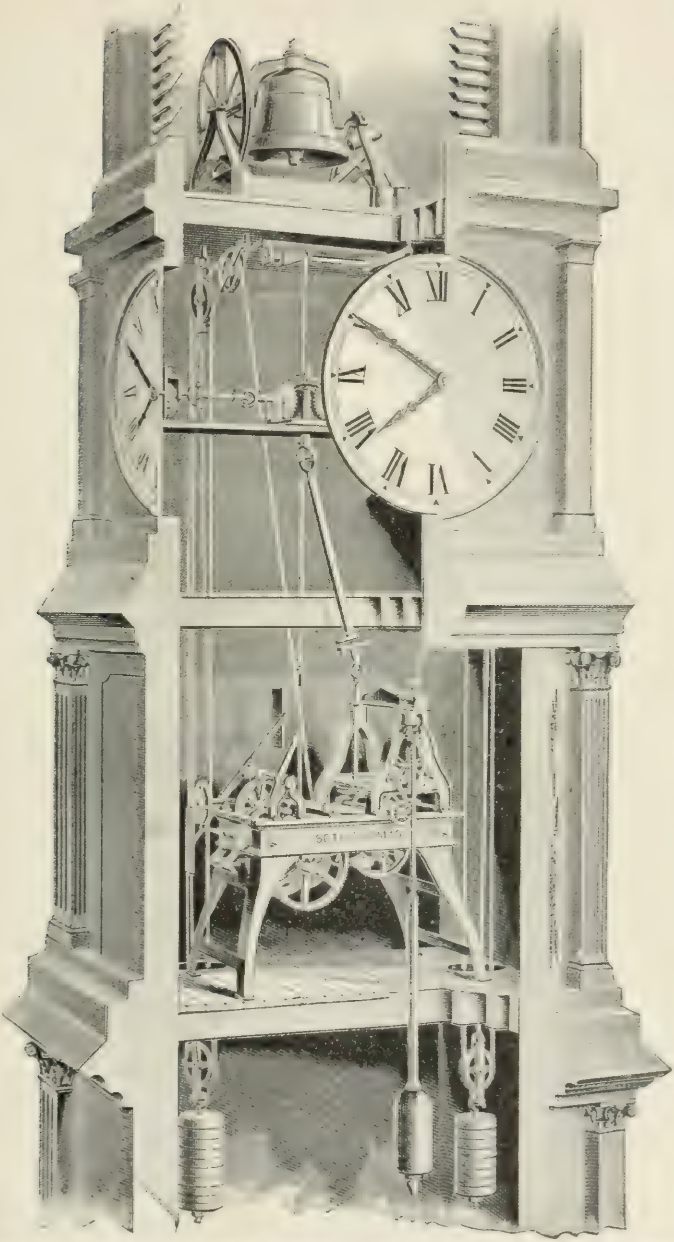


FIG. 207. — A TOWER CLOCK MOVEMENT, DIALS AND BELL, AS ARRANGED IN A TOWER.

enth, and tenor of a peal of eight, the tenor to weigh —— pounds.

2. The dials to be made of ——. If illuminated, the dials to be of opal glass, 22 ounces per square foot, with the figures and minutes of cast-iron in rings. There are to be no bars radiating from the center. The opening in the wall is to be the full diameter of the dial.

3. The minute hands to have short external counterpoises, painted the same color as the dial. If illuminated, the hands and figures to be black, with the framework of the dial in gilt. If not illuminated, the hands and figures to be gilt on a black background.

4. The escapement to be a double three-legged Denison gravity.

5. The pendulum to have zinc and iron compensation, to weigh about 200 pounds, to beat seconds and a half, and swing through a total arc of 5°; or the pendulum to have mercury compensation with a steel tube and cast-iron pan. To be provided with a divided arc to observe the arc of swing and a safety device in case the pendulum spring breaks.

6. The clock must set on stone corbels or I-beams or brackets bolted through the wall. The pendulum cock to rise from the clock frame.

7. There must be a minute dial and a dial for seconds attached to the movement.

8. The clock to run a little more than eight days and have ample maintaining power while being wound.

9. The striking and chiming parts to be wound up every —— days. The fourth quarter bell to have two hammers.

10. The striking of the hours to be started independently of the quarters, the first blow of the hour to be struck exactly on the hour; the quarters to begin at 15, 30, and 45 minutes.

11. The hour hammer to be not less than one sixtieth of the weight of the bell, and to be raised not less than nine inches; the quarter hammers to increase in weight from a

sixtieth to a fortieth of the weight of their bells, to be raised not less than six inches.

12. The small wheels to be of brass or hard gun-metal, the large wheels may be of cast-iron. The pinions and arbors to be of steel and all bushings of brass.

13. The drums to be sufficiently strong; the wire rope to be one fourth inch in diameter and not wound more than one layer on the drum.

14. The fan-flys to be at the back or above the clock and large enough to make the striking uniform and sufficiently slow.

15. All the metal except working surfaces to be painted some color (not black, as it is too hard to see).

16. There must be something to warn or stop the winding; and some device to catch the weights if they fall.

17. All shafts to be made to be taken out separately by unscrewing the bushings.

18. The clock to be inclosed in a room or case to keep out unauthorized persons, to protect it from dust and dirt, and to avoid sudden temperature changes and strong draughts.

The care of a tower clock. — In order to get the best results there is need of intelligent oversight and careful handling in connection with a big tower clock. Every janitor of a church or public building is not capable of taking care of one. There are several matters to which particular attention should be called.

In the first place all parts of the clock must be kept well oiled. This applies also to the pulleys and wire ropes. The pulleys should be well oiled to prevent friction and the wire ropes should be oiled to keep them from rusting and thus wearing out sooner. Some good mineral oil is best for the wire ropes. If the oil on the parts of the clock becomes discolored and dirty they should be wiped clean and fresh oil applied. No oil should be applied where the beat pins touch the pendulum. There is no disadvantage in an excess of oil if it is wiped away before it gets thick and gummy.

The winding should be done carefully and at definite

times. It is preferable to have a stop or automatic signal when one comes to the end of the winding. If this is not provided, then the wire rope should be marked so that it can be readily seen when the winding is nearly finished. There is great danger in coming up to the end with a bang. A pulley is likely to be torn loose or the wire rope broken and the weight allowed to fall. The striking and chiming weights must not be wound when the clock is about to strike or chime. No maintaining power is ordinarily supplied for these.

Nearly every tower clock has some arrangement for setting it ahead or back a small amount. Sometimes there is a knob with a little hand attached to it which can be moved over a dial divided into seconds. It is then easy to set the clock ahead or back a few seconds or even a minute or so. This works exactly like "the slow motion screw" on many pieces of physical apparatus. Sometimes there is a circular disc with holes in it and opposite these is a plug which fits into them. The clock is set by moving the plug ahead or back a few holes. If the clock has a three-legged gravity escapement, then there is no need of a separate device for setting the clock, as it can be done with great ease and without danger through the escapement. If it is too fast, simply hold the double three-legged escape wheel still for the correct number of seconds. If it is too slow, then pull both arms away from the pendulum. The escape wheel will then begin to turn rapidly and soon run off the desired number of seconds or minutes. If the tower clock is a good one and keeps good time, it ought to be set whenever it is twenty seconds off. It will often require a month or more for this to occur.

Sometimes it is necessary to regulate the clock to make it run a little faster or slower. The pendulum usually has a screw at the top so that its length can be changed. If this is done it is ordinarily necessary to unscrew the clamp from the pendulum spring before turning the screw which lengthens or shortens the pendulum. (See Figs. 204, 205.) This, however, is not the best way to regulate the clock, un-

less the desired change amounts to more than, say, two seconds per day. In other words, regulate the clock within two seconds a day by lengthening or shortening the pendulum and then use the following method: On nearly every pendulum a short distance above the bob will be found a little pan, fastened to the pendulum, in which small weights may be placed. Since this pan is above the center of gravity of the pendulum, adding small weights will make the clock go faster and taking some out will make it go slower. Pennies may be used for these small weights, or small pieces of lead, or, best of all, wire nails. It must be determined first how much difference one wire nail in the pan makes in the running of the clock. To do this let the clock run for a week and determine how much it has lost or gained. Then put ten nails in the pan and determine how much difference occurs in the rate of running the following week. This will give the effect of ten and thus one nail. Perhaps it will be found that one nail changes the rate one third of a second a day. From now on regulation is easy, because one knows the number of nails to use to get the desired effect.

There are different ways of treating a clock as regards setting and regulating it. The three best will now be described. The easiest and simplest is to let the clock alone and simply set it every time it is twenty seconds off. If it eventually seems to be persistently losing and one wants to try to regulate it more closely, then add the proper number of nails and again leave the clock alone until it has clearly demonstrated that it is steadily losing or gaining. A written record should of course be kept of its behavior. Another way to treat the clock is to regulate it every time it is set. Thus if it has lost twenty seconds and must be set, add as many nails as seem necessary to make it go exactly right. Possibly the matter was overdone and the next time it was twenty seconds fast when setting became necessary. Then take out a sufficient number of nails to make it go exactly right. This method without doubt requires the least setting but the clock never settles down for

a long period to the same rate. The third method is not the best, but is good when an inexperienced person who does not keep a record of the running of a clock has it in charge. One weight sufficiently large to change the rate about two seconds is used. When the clock gets slow (twenty seconds or more) add the weight. It will begin to gain and eventually be fast. When twenty seconds or more fast, take off the weight. It will begin to go slow and eventually be behind. If this method is used it is not necessary to set the clock and the regulation has become a very simple matter.

The question of ventilation in connection with a tower clock is one about which there are differences of opinion. Some advocate inclosing the clock in a room as nearly air-tight as possible. This will exclude dust and dirt, keep out a large amount of moisture, and eliminate abrupt changes in temperature. When the temperature outside rises above the temperature inside, moisture is apt to condense on the clock and this is very bad. The best plan is perhaps to avoid ventilation in winter when the clock room is presumably quite a little warmer than out of doors. The pendulum should never be in a draught of air. Heavily oiled floors go a long way towards keeping down dust.

One of the greatest troubles in a cold climate is the prevention of frost work on the wheels near the dials. For a climate where the temperature goes far below zero (F.) and there are sudden changes in temperature the best arrangement is to have the bells on a floor above the dials and to have the clock work on the same floor as the dials. The clock room can then be kept fairly warm and since the dials can be solid the space back of them is usually quite a few degrees warmer than out of doors. This reduces frost work to a minimum. Coating the gears with near fluid oil also helps. If the bells are on the same floor as the dials, then the clock work must be on a lower floor. This is particularly conducive to the formation of frost work. In such an arrangement the rods and gears are sometimes

boxed in and electric lamps placed in these boxes to serve as heaters when necessary.

Sometimes a tower clock stops and there is no apparent reason. It has not run down and nothing has broken. Usually if no one has tried to do something before the caretaker arrives, the cause of the stopping is evident. The more usual causes are these. Frost work on the gears and rods near the dials; a swelling of the weight boxes so that the weights have been pinched; lack of oil or too much dirt and gummy oil on the parts; a failure of the striking or chiming mechanism to operate causing the mechanism to "jam" in some clocks at the next quarter or hour, a strong draught of air on the pendulum.

The accuracy of tower clocks. — A first class modern tower clock ought to run within five or six seconds a week — about half a minute a month. To put it differently the clock ought to maintain a constant rate for a period of several months within a second or a little less. The following table gives the errors and rates of a first class modern tower clock with four eight-foot dials and chimes for a period of a little more than four months. The clock was set twice but not regulated during this period. It will be seen that it ran well within the limits set in the opening sentences of this paragraph. The average value of the rate was -0.61^s, while the largest and smallest values were -1.67^s and -0.19^s.

Date	Error	Rate	Date	Error	Rate
June 8, 1917	5.0^s Slow		The clock was set right.		
11	4.0^s Slow	-0.33^s	Aug. 1	0.0^s Fast	
16	1.0^s Slow	-0.60^s	6	2.0^s Fast	-0.40^s
23	4.0^s Fast	-0.71^s	25	10.0^s Fast	-0.42^s
28	5.0^s Fast	-0.20^s	Sept. 6	15.0^s Fast	-0.41^s
July 10	12.0^s Fast	-0.58^s	19	19.0^s Fast	-0.31^s
14	14.0^s Fast	-0.50^s	The clock was again set right.		
18	16.0^s Fast	-0.50^s	Sept. 21	3.0^s Slow	
24	19.0^s Fast	-0.50^s	Oct. 2	1.0^s Slow	-0.19^s
27	22.0^s Fast	-1.0^s	13	14.0^s Fast	-1.36^s
30	27.0^s Fast	-1.67^s	18	17.0^s Fast	-0.60^s

Some famous modern tower clocks. — The most famous modern tower clock in the world is probably the Westminster clock on the Victoria Tower of the Houses of Parliament in London. A general view of it is given in Fig. 208. This clock has an interesting history and is a model of accuracy. Unfortunately there was some controversy associated with its history and that of the bells.

Its history begins about 1844, while the tower was in process of construction. It is probable that the architect had made up his mind to have Mr. Vulliamy make the clock. His plans were sent in as early as 1846 but were not considered suitable by the Astronomer Royal for so large a clock. Plans were also submitted by Whitehurst of Derby and by E. J. Dent, of the Strand, London. In November, 1851, Mr. E. B. Denison was asked to act as referee with the Astronomer Royal. He was then a barrister of some repute but turned his attention to clocks and bells and became eventually very widely known. He was born in 1816 and died in 1905. In 1874 he succeeded his father as baronet, taking the title of Sir Edmund Beckett. In 1886 he was called to the House of Lords under the title of Baron Grimthorpe. He is the author of the very interesting and valuable book entitled *Clocks and Watches and Bells*, which has gone through many editions and had a very large sale.

At this time, 1851, Whitehurst's plans were not to be found, and, since he had died, nothing further could be done. Denison also disapproved of the Vulliamy plans. It was finally decided in 1852 to have Dent make the clock. There were two specifications laid down which made most tower clock makers think that no clock could be constructed which would fill them. The first was that it was to keep time within one minute a week and the second that the first stroke of the hour was to be within a second of the true time. Dent only consented to make the clock from plans which were to be furnished him by Denison.

The clock was accordingly made by 1854 and set running in the factory. In the meantime, 1853, Mr. E. J.

FIG. 208. — THE WESTMINSTER CLOCK ON THE VICTORIA TOWER OF THE HOUSES OF PARLIAMENT IN LONDON.

Dent had died and the work was carried on by his son. In 1859 the clock was installed in the tower and in 1860 it was set going. It proved to be a model of accuracy and keeps time within a few seconds a week. The clock carries the inscription "This clock was made in the year of our Lord 1854 by Frederick Dent of the Strand and Royal Exchange, Clockmaker to the Queen, from the design of Edmund Beckett Denison Q. C." It was for this clock that Denison invented the double three-legged gravity escapement.

The tower is 40 feet square and the four dials are 23 feet in diameter and 180 feet from the ground. The dials have a cast-iron framework filled with opalescent glass and are illuminated at night. The hour hands are solid and made of gun-metal. The minute hands, to make them lighter, are hollow copper tubes reinforced with internal diaphragms. They are 9 feet and 14 feet long, respectively.

The frame for holding the movement is 15½ feet long and 4 feet 7 inches wide. The pendulum is 13 feet long, beats two seconds, and weighs about 700 pounds. It requires about 20 minutes to wind the running part once a week. The striking and chiming parts are wound twice a week and the time required is several hours. The escapement is the double three-legged gravity.

The hour is struck on Big Ben II, a giant bell, weighing 13 tons and 11 cwts. The Westminster or Cambridge chimes are rung on four bells weighing 3 tons 18 cwts., 1 ton 13½ cwts., 1 ton 6 cwts., and 1 ton 1 cwt., respectively. The clappers for these five bells weigh 766, 175, 80, 60, and 56 pounds, respectively.

These bells also have an interesting history tinged with a bit of controversy. In 1856 the matter of the bells was also put in Denison's hands. Specifications were prepared and submitted to three English bell-founders. One of them undertook to make the bells and made the great one first. This bell, Big Ben, came out thicker than the pattern, and two tons heavier than was intended, and required a clapper twice as heavy as was intended. It cracked after a few weeks of use and it was found on examination that

there was a great flaw where the two streams of molten metal meeting round it had never joined. It was eventually recast by another bell-founder. Big Ben II also partially cracked after a few months striking and those who would paint things as black as possible claim that it was a defective casting, porous, and unhomogeneous. It has been turned so that the hammer strikes in a different place and a lighter hammer is used. The four smaller bells were successfully cast the first time. The total cost of the bells, their support, the hands and dials, and the clock movement was about £20,000.

The largest four-dial tower clock in England is said to be the electrical clock in the tower of the Royal Liverpool Society's new building in Liverpool. The makers were Gent & Co. of Leicester. The dials are 25 feet in diameter and 220 feet above the ground.

The largest four-dial tower clock in America is the one on the tower of the Metropolitan Life Building, Madison Square, New York City. It is pictured in Fig. 209. The tower has a frontage of 75 feet on Madison Avenue and 85 feet on Twenty-fourth Street and is 700 feet high. Its construction was finished in 1909. The four dials are 26 feet 6 inches in diameter and 346 feet above the sidewalk. The dials are built up of reinforced concrete faced with vitreous blue and white mosaic tile. The figures on the dials are four feet high and the minute marks are 10½ inches in diameter. The minute hand measures 17 feet from end to end, 12 feet from center to point, and weighs 1000 pounds; the hour hand measures 13 feet 4 inches from end to end, 8 feet 4 inches from center to point and weighs 700 pounds. They are built on iron frames, sheathed with copper, and revolve on roller bearings. The hour is struck on a 7000-pound bell with a hammer weighing 200 pounds. The Cambridge or Westminster chimes at the quarter hours are struck on four bells, the largest weighing 7000 pounds (key of B flat); the second, 3000 pounds (E flat); the third, 2000 pounds (F natural), and the smallest, 1500 pounds (key of G). They are mounted on pedestals between the

FIG. 209. — THE METROPOLITAN LIFE BUILDING, MADISON SQUARE, NEW YORK CITY.

marble columns outside the forty-sixth story, and are said to be twice as high above the sidewalk as any other large bells in the world.

As the evening darkness draws near, at any predetermined hour for which the mechanism may be adjusted, hundreds of electric lights appear back of the dial numerals, the minute marks and the entire length of the hands, all of which are brilliantly illuminated with splendid effect — a feature never produced by any other clock in the world.

Simultaneously with the illumination of the hands and dials, an automatically actuated switch lights up a great electric octagonal lantern, eight feet in diameter, located at the top of the tower, from which powerful electric flash-lights, marking the hours in the evening, may be seen for a great distance, far beyond any possible transmission of sound, the time being signaled therefrom as follows:

Each of the quarter-hours is flashed in red and the hours in white light. One red flash for the quarter, two red flashes for the half, three red flashes for three-quarters, and four red flashes for the even hour — these latter flashes followed by a number of white flashes marking the hour.[1]

It is an electrical clock made by the Self-winding Clock Company of Brooklyn, N. Y. The description of the works will thus be deferred until the next chapter in which electrical clocks are treated.

This clock is also a model of accuracy. It seldom gains or loses more than one or two seconds a day and is set right as soon as it is a few seconds out.

The oldest tower clock in New York City is the church clock in the tower of St. Paul's Chapel. It was built in 1766 and attended by Washington, whose pew remains. It is pictured in Fig. 210. The clock was made by John Thwaites of London in 1798. Of late years it has begun to show its age. It is erratic and no longer keeps up to the modern demand for accuracy.

The largest single dial clock in this country is the ad-

[1] Quoted almost exactly from a pamphlet: "The Metropolitan Life Building," issued by the company.

Copyright by Underwood & Underwood, N. Y.

FIG. 210. — ST. PAUL'S CHAPEL, NEW YORK CITY.

vertising clock of Colgate & Company, located on their factory in Jersey City and overlooking New York Harbor. The dial is 38 feet in diameter and the hands are about 20 and 14 feet long. The hours are indicated simply by black marks about $5\frac{1}{2}$ feet long and 2 feet wide. This clock was put up in 1906.

One of the largest clocks in the world, perhaps *the* largest, is located in Malines (or Mechelen), Belgium. Near the center of the city stands the old Cathedral of St. Rombaut, completed in 1312. It has a huge unfinished tower 320 feet high. The proposed height was 460 feet or more. On this tower, about 300 feet above the ground, are the great dials, 44 feet in diameter. They are in bad repair at present, hardly visible from the street, and no longer used as a clock. The clock had but one hand, the hour hand, and was constructed in 1708 by the clockmaker Jacques Wilmore, English by birth but living in Malines. In the marketplace near by is a huge stone circle indicating the size of these dials.

Bells should perhaps not be treated in a book on time and timekeepers. Nevertheless nearly every tower clock strikes the hours on a bell and may have chimes which require several bells. Something about bells may, therefore, be of interest.

Bells have been known for four thousand years or longer. They go back at least to the time of Moses, as they are mentioned in the Book of Exodus. It is impossible to trace bells to their origin. They seem to have been known from the earliest times and by all peoples. These early bells were not cast but hammered into shape. They were small and often if not usually made of gold. Cast bells did not appear until the fourth or fifth century A.D. It is generally supposed that they were first made by the Christians, but by what person they were first introduced it is impossible to say. At any rate, they antedate clock mechanism by a good many centuries.

Modern bells are made of bell-metal, which is an alloy of copper and tin. The best ratio is considered by most to

be thirteen parts copper to four of tin. This ratio is, however, not strictly adhered to, and the composition used by different bell-founders is slightly different. Iron bells have been made but they are not satisfactory as to tone. The addition of silver to the copper-tin alloy has been tried but there are no advantages gained.

The largest bell in the world is the oft-mentioned broken bell of Moscow, which is not located in a tower but rests upon the ground. It is sometimes called Czar Kolokol — the Emperor of Bells. Its weight is variously estimated from 220 to nearly 250 tons. It is nineteen feet high and nineteen feet in diameter. It was cast by order of the Empress Anne in 1733. The bell was originally suspended from beams, but these, when destroyed by fire, permitted the heated bell to drop and break. The Emperor Nicholas had it raised in 1836 and placed upon a low circular wall in the Kremlin. It is pictured in Fig. 211. A complete list of all the bells in the world weighing over twelve tons cannot be given, as so many of them are located in Russia, China, and Japan and their fame has not yet spread abroad. There would probably be from 20 to 40 bells in such a list. A bell in the Cathedral of Moscow which is rung twice a year weighs about 60 tons. The "Great Bell of China," in Pekin, weighs about the same. A bell in the Buddhist monastery Chi-on in Kioto, Japan, is said to weigh between 80 and 90 tons. Three more large bells may be mentioned which are or have been in constant use and are well known. The Cologne Cathedral bell was cast in 1874, weighed a little over 25 tons, had a clapper weighing 1530 pounds, and was 15 feet 2 inches in diameter. This bell no longer exists. During the war Germany was forced to sacrifice it in order to get the much needed metal of which it was made. It was sawed in pieces and removed from the tower. It is perhaps fitting that this bell which had its birth in war should have been dissipated in war. French guns captured in 1870 and 1871 were the material from which the bell was originally made. The bell in St. Paul's in London was cast in 1882, weighs 16 tons 14 cwt., has a clapper weighing

730 pounds, and is between 9 and 10 feet in diameter. The Westminster bell has already been mentioned. It was cast in 1858, weighs 13 tons 11 cwt., has a clapper weighing 766 pounds, and is 9 feet in diameter. The largest bell in America is the bell in the Cathedral at Montreal, which

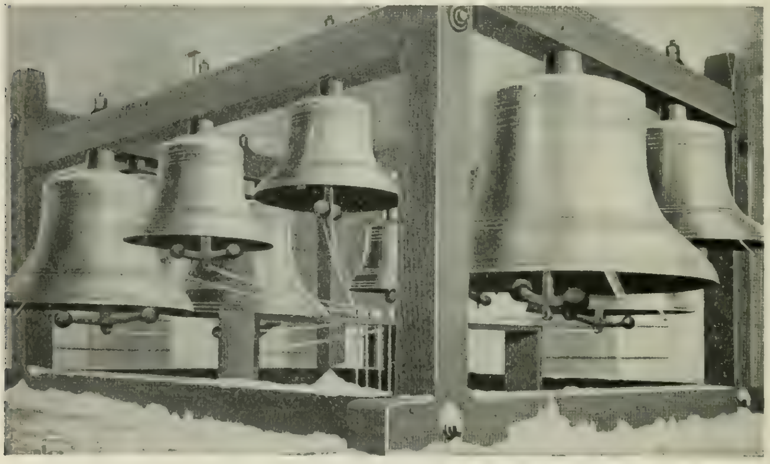
Courtesy, Meneely Bell Co., Troy, N. Y.

FIG. 211. — THE GREAT BELL OF MOSCOW.

weighs nearly 15 tons. These figures for bells are not always exact. They are usually determined by computation. Sometimes they are only estimates and differ greatly with different writers.

The method used in casting a bell is very interesting. It is nearly the same everywhere. The internal mold or

core is made of brick or cast-iron and covered with molding clay. This is given the shape of the inside of the bell by means of a sweep or crook. The older method is to make a model of the bell out of clay on the core. When this is dry, the outside mold or cope is made on the top of the model. The cope has hair, hay-bands, and perhaps iron bands worked into it to make it hold together so that it can be lifted off when dry. The cope is lifted off, the model clay bell is knocked to pieces and removed, and the cope is then



Courtesy, Meneely Bell Co., Troy, N. Y.

FIG. 212. — CHIME OF TEN BELLS IN TOWER OF COURT HOUSE AND CITY HALL, MINNEAPOLIS, MINN.

replaced. The molten metal is then poured in at the top. A bell is always cast mouth down. In the newer method no model bell of clay is made. The outside mold or cope is an iron case lined with clay and this is given the shape of the outside of the bell.

Among American bell-founders the two best known are probably the Meneely Bell Company, 22–26 River Street, Troy, N. Y., and the E. W. Vanduzen Company, 651 East Second Street, Cincinnati, Ohio. Casting bells is a limited business, so that there are few firms engaged in it. The

Meneely Bell Company is without doubt the largest and oldest firm of bell-founders in this country. It consists of father and three sons. Bell making has been a family occupation for generations, as their ancestors in Connecticut cast the first bells in America. Among the many well-known bells made by this firm may be mentioned the bells for the big clock on the Metropolitan Life Insurance Building in New York City, the new "Liberty Bell" for Philadelphia, and the chime of ten bells for the Court House and City Hall in Minneapolis, Minn. These last are pictured in Fig. 212. Their exact method of casting a bell, as they describe it, is as follows:[1]

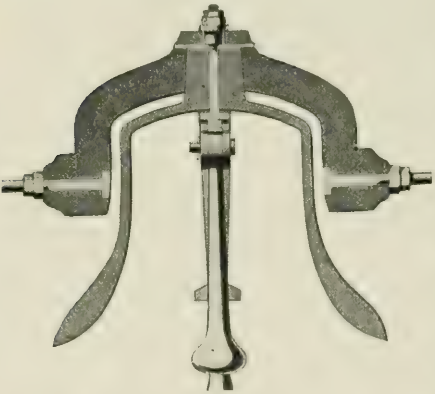
All of our bells are moulded in perforated iron cases (Fig. 213), by the use of which we are enabled to secure castings thoroughly sound and excellent in finish, and therefore capable of producing clearness of tone. The accompanying cut shows the form of these cases. Porous loam and other substances compose the material which is put upon the cases in varying thickness, to which the necessary form and finish are given by the use of sweep patterns, shaped in such a manner as to secure, by their revolution about a common center, surfaces corresponding to the outer and inner portions of the intended bell. As bell metal shrinks in cooling, the inner case, before the loam is placed upon it, is wrapped about with straw rope, charring of which, by the heat of the metal in pouring, gives room for the necessary contraction, and prevents the straining of the metal. The moulds are closed upon each other in a manner securing exact regularity of thickness in the space within. The metal is poured in at the head. The gases generated in the metal, and which, if allowed to remain in the moulds, would

FIG. 213. — MOLDING CASES FOR BELLS.

[1] Taken from the beautifully illustrated and interesting pamphlet, *Meneely Bells*, issued by the Meneely Bell Co., 22–26 River St., Troy, N. Y.

produce an explosion, or at least cause a porous casting, find vent in the perforations. These cases, also, to the advantage of the bell, allow it to cool, after casting, in such a manner as to secure precise uniformity throughout.

The general shape of a bell is too well known to need description or illustration. Nevertheless, the exact shape and relative dimensions of the different parts of a bell calculated to give the best tone is a matter to which a great deal of thought and experiment has been devoted. A shape often used is that illustrated in Fig. 214. This illustration also shows the method of attaching the clapper and the rotary yoke for holding a bell. The thickness of a bell at its thickest part, called the sound bow, is usually made one thirteenth of its diameter. Smaller bells tend to be a little thicker than this ratio would call for. Bells are made to exact formulas, so that given the diameter of a bell it is possible to calculate every dimension, the weight of the bell, and its (musical) note or tone. The number of vibrations produced in a bell in a given time (tone) varies, directly, as the square of the thickness, and inversely, as the bells' diameter, or as the cube root of its weight.



Courtesy, Meneely Bell Co., Troy, N. Y.

FIG. 214. — THE EXACT SHAPE OF A BELL.

Clock bells are rung by raising a hammer a certain distance and allowing it to fall on the bell. A hammer usually has about one fiftieth the weight of the bell. Two ways of arranging the hammer to be operated by the clock are shown in Fig. 215. In each case there must be a weak check spring to take the hammer off of the bell as soon as the blow has been struck. These are shown in the figure. Some-

times a simple block of India rubber is used instead. This normally keeps the hammer just clear of the bell but is sufficiently compressed by the blow to allow the hammer to reach the bell.

Many tower clocks have chimes at the quarters and before the strokes of the hour. For these several bells are necessary. The most famous of all chimes are without doubt the Cambridge or Westminster chimes devised presumably by Dr. Crotch in 1780. Four bells are required,

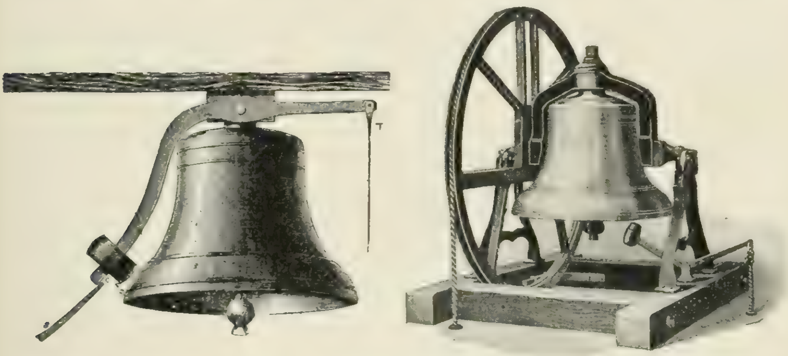


FIG. 215. — TWO METHODS OF ARRANGING THE HAMMER TO BE OPERATED BY A CLOCK.

and they must be 1, 2, 3, and 6 in a peal of 6. The bells struck at the first, second, third, and fourth quarter and the order is here given.

First.	1, 2, 3, 6	Third.	1, 3, 2, 6	Fourth.	3, 1, 2, 6
Second.	3, 1, 2, 6		6, 2, 1, 3		3, 2, 1, 3
	3, 2, 1, 3		1, 2, 3, 6		1, 3, 2, 6
					6, 2, 1, 3

It will be noticed that the first five and last five groups of four are the same. The famous clock on the Houses of Parliament has these chimes. Here the notes are B, E, F sharp, G sharp. The Madison Square clock in New York City also has them and here the notes are B flat, E flat, F, and G. There are other chimes on four bells and many chimes requiring a larger or smaller number of bells.

CHAPTER XVIII

THE HISTORY AND CONSTRUCTION OF ELECTRIC CLOCKS

The term "electric clock" in its broadest sense is applied to any clock in which electricity is used in any way. There are, in fact, three ways in which electricity may be used. In the first place, it may be used directly or indirectly to furnish the driving power for the clock. There are three ways in which this may be done: (1) It may be used to keep the pendulum swinging, in which case the usual clock principle is reversed. Usually, the clock gives an impulse to the pendulum to keep it swinging. Here the pendulum is forced to swing and drives the clock; (2) It may be used to raise a weighted lever periodically which engages with some wheel of the train. A mainspring or weight is then no longer needed to drive the clock; (3) It may be used to wind up the mainspring or weight periodically, perhaps at the end of each hour. Such clocks are usually called self-winding clocks. In the second place, electricity may be used to move the hands of a clock at a distance in harmony with the hands of a master clock. The so-called "minute-jumpers" are of this kind. In the third place, it may be used to set the hands of a clock periodically, perhaps once an hour, in agreement with a master clock. Such clocks are called synchronized clocks. In the same clock electricity may be used in the first and third ways or in the second and third ways at the same time.

A complete treatment of the subject would call for a detailed description of the construction and action of typical electrical clocks of these five kinds, and there are many of them. This is impossible. Thus the general principles and a few examples only will be given. The synchronized self-winding clocks made by the Self-winding Clock Company of Brooklyn, N. Y., and used by the Western Union Tele-

graph Company for their system of controlled clocks are probably the most common, although many electrical clocks are made by the Seth Thomas Clock Co. of Thomaston, Conn., and the E. Howard Clock Co., of Boston, Mass., and others.

The history of electric clocks covers less than eighty years. Credit is usually given to Alexander Bain in 1840, for being the pioneer and making the first attempts to apply electricity to clocks. Since then, much attention has been paid to the subject, and there are probably nearly a thousand patents in the United States and Great Britain covering some form of the application of electricity to clocks. Most of these inventions are useless. In some cases a few clocks have been manufactured but the total number of electrical clocks in this country is small, probably well under a million, and more than half of them have been made by one firm. Electrical clocks at present are too troublesome and too uncertain to come into extended use. And yet electricity is a magic word, and many people suppose that if electricity is used in some way in connection with a clock it is far better and more satisfactory than the ordinary clock. As a matter of fact, new troubles and worries have been introduced. It is not intended to intimate that electrical clocks are not sometimes a necessity. A manufacturer wishes to have accurate and uniform time in all parts of a large plant. A system of electrical clocks is necessary. This system will require far more care and attention, however, than a single good mechanical clock.

Electricity as the driving power. — The first way to use electricity as the driving power is to so arrange matters that an electro-magnet gives an impulse to the pendulum periodically and thus keeps it swinging. The clock consists of the usual indicating mechanism and time train, or part of it. The escapement might perhaps better be called a *propel-ment*, if a new word may be coined. In the ordinary clock one tooth escapes and gives the pendulum an impulse for every swing of the pendulum. Here the pendulum is forced to keep swinging and drives or propels the

escapement forward one tooth for each swing. This so-called escapement must naturally have an entirely different form from any ordinary escapement. There is, of course, no mainspring or weight. One way to keep the pendulum swinging is to have the clock make contact every swing or every ten beats. The current is then sent through an electro-magnet which is so placed as to give a pull in the right direction to the pendulum, which carries a coil of wire. This arrangement is not the best, however, as the amount of impulse given the pendulum would depend on the strength of the battery. This varies somewhat from time to time and grows less as the battery weakens from age and use. A better way is to have the current, when contact is made, raise an armature which will fall as soon as the current is cut off and thus give the pendulum an impulse. Here the amount of the impulse is independent of the battery. It need only be strong enough to be able to pull up the armature. In some clocks it is so arranged that contact is made not every beat or every ten beats but whenever the arc of swing of the pendulum has fallen below a certain value. This again makes for greater regularity and independence. In fact, two principles which might well be laid down for pendulum-driven electric clocks are (1) that the impulse to the pendulum must be independent of the strength of the battery and (2) that the impulse must be given not every so often but whenever it is needed, as shown by the decreased arc of the pendulum. One of the great difficulties of electric clocks is poor contacts. The contact parts are usually of platinum, but a film of oxide soon forms and over this a film of dirt or oil.

A second way to make use of electricity to drive a clock is to use it to raise a weighted lever periodically. Such a clock would have the usual indicating mechanism, time train, and controlling mechanism. There would be no spring or weight. Instead a weighted lever is used which engages with one of the wheels of the time train or some special wheel firmly fastened to one of the arbors of the time train. Contact is made periodically, in one clock every

seven minutes. The current actuates an electro-magnet which raises the weighted lever and thus supplies power for a further run.

The third way to utilize electricity as the driving power is to have it wind up the mainspring or weight periodically. This is the method used by the Self-winding Clock Co., of Brooklyn, N. Y. In their clocks a spring is used and it is wound up every hour. The clock has the usual indicating mechanism and time train. The controlling mechanism is an anchor escapement and pendulum. The driving mechanism is a spring. It is thus a clock of the usual construction. Each hour the clock makes contact. This sends the current through a little motor which winds up the spring. It is wound just one turn and then the circuit is broken for another hour. The same amount of expansion of the mainspring is thus used each hour. One of these clocks is illustrated in Fig. 216. In Fig. 217 is shown the movement of the clock. All of the parts are evident; the motor is at the bottom.

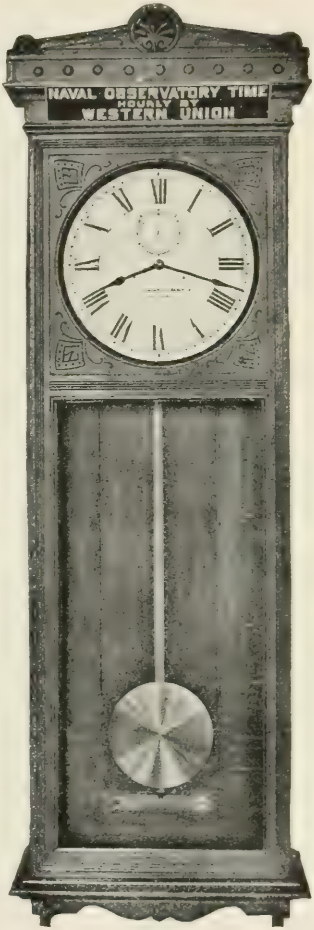


FIG. 216.—A SELF-WINDING CLOCK AS MADE BY THE SELF-WINDING CLOCK CO.

In Fig. 218 is shown the movement of a self-winding master clock, as made by the Seth Thomas Clock Co. of

Thomaston, Conn. The motor is at the bottom. It is not of the rotary type but operates by breaking contact.

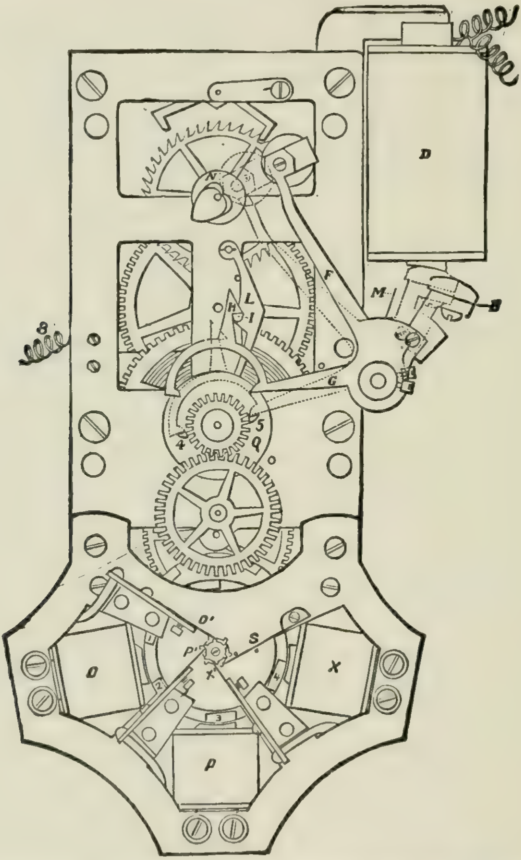


FIG. 217. — THE MOVEMENT OF A SELF-WINDING CLOCK.
(From GOODRICH, *The Modern Clock*.)

Secondary dials. — Electricity may also be used to move the hands of a controlled clock in unison with those of a master clock. Such a clock is generally very simple in construction and is often spoken of as a secondary dial or minute jumper. One simple arrangement of the necessary

mechanism is shown schematically in Fig. 219. Contact is made and the circuit closed by the master clock every minute. When the current passes through the electro-magnet *M* the armature is pulled up and this pulls the toothed wheel forward one tooth. When the circuit is broken the spring *S* pulls the armature back into its original position against the stop *K*. If this simple mechanism were to move a minute hand forward one minute each time the circuit was closed, it would be necessary to attach a pinion with 8 leaves to the axle carrying this toothed wheel with 16 teeth and to have this pinion drive a wheel of 30 teeth. A hand attached to its arbor would then turn in 60 minutes. The arrangement for preventing the toothed wheel from moving backward is evident at *A* in the figure. The mechanism is simplicity itself, but the great trouble lies in the master clock. Should contact fail to be made, the controlled clock becomes one minute slow and there is no automatic way of correcting the error.

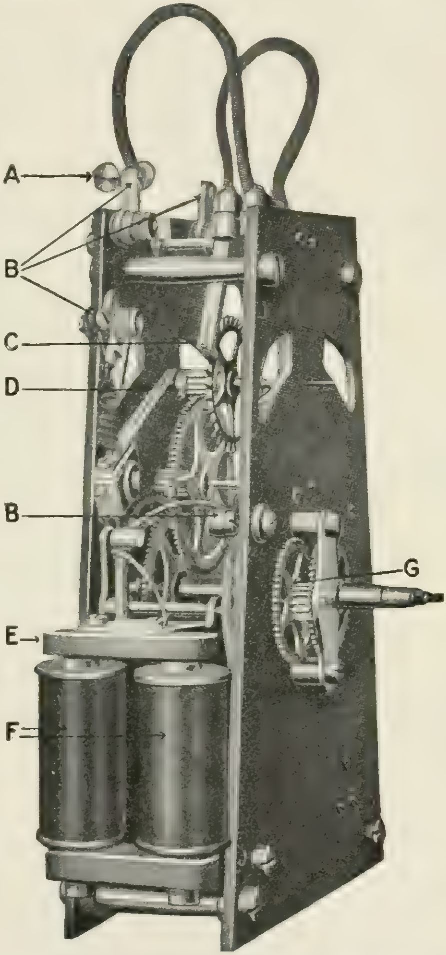


FIG. 218. — THE MOVEMENT OF A SELF-WINDING MASTER CLOCK AS MADE BY THE SETH THOMAS CLOCK CO.

In Fig. 220 is illustrated the actual movement of a secondary dial as made by the Seth Thomas Clock Co. The various parts and their operation are evident in the light of the explanation which has just been given.

It will be remembered that the great tower clock on the Metropolitan Life Building in Madison Square, New York City, which was described in the last chapter, was an electric clock. It is a controlled clock, operated very much as has just been described. The master clock is in the Directors' room on the second floor. It is about eight feet tall and has a very fine mahogany case. In fact it looks like a very large and handsome grandfather clock. It has an anchor escapement and a compensated pendulum. Every minute and also at the quarter and at the hour it makes a series of contacts. Each minute when contact is made the current is switched on the four electric motors which turn the hands forward exactly one minute. It requires about 45 seconds to do this. The circuit is then broken. Thus the hands move forward one minute in about 45 seconds and then remain stationary for 15 seconds until contact is made once more. The ringing of the chimes at the quarters, the striking of the hour, and the lights at night are all operated by the contacts made by the master clock.

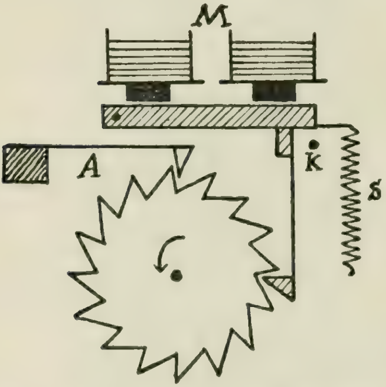


FIG. 219. — DIAGRAM ILLUSTRATING THE NECESSARY MECHANISM FOR A SECONDARY DIAL.

Synchronized clocks. — Electricity may also be used to set a clock periodically, say every hour, in agreement with a master clock. Such clocks are usually called synchronized clocks. One simple way of doing it is to have an electromagnet draw up an armature and bring a wedge-shaped piece into forcible contact with a heart-shaped cam and

thus turn it into the proper position. The minute hand or second hand is attached to the arbor, which carries this cam. The self-winding clocks used by the Western Union Telegraph Co. are synchronized clocks. The arrangement for synchronizing them can be easily seen in Fig. 217. It

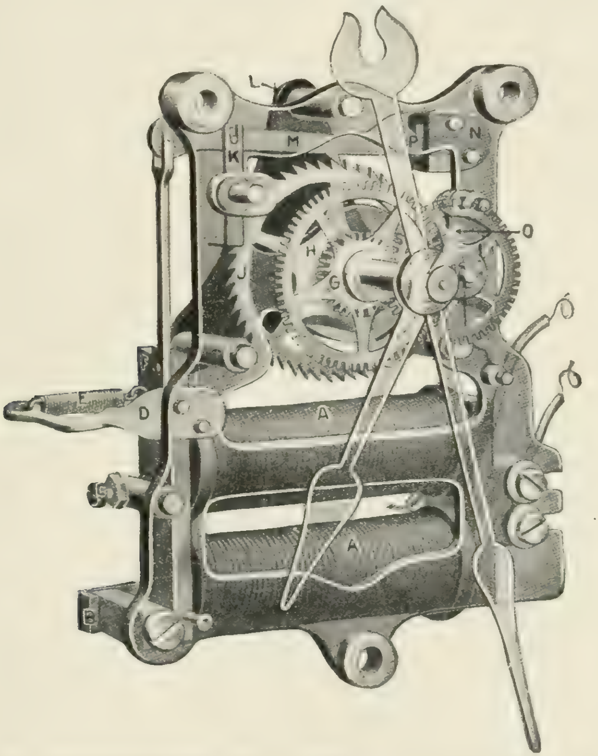


FIG. 220. — THE MOVEMENT FOR A SECONDARY DIAL AS MADE BY THE SETH THOMAS CLOCK CO.

will be seen that these clocks are both self-winding and synchronized clocks.

Another simple device for setting a clock in agreement with a master clock is shown in Fig. 221. The two pins P_1 and P_2 are attached to the armature of an electro-magnet. When the current is sent by the master clock, these two

pins are moved down forcibly and by means of a pincers-like action set the hand to the exact hour. When the circuit is broken, the spring at S returns the pincers-like arms to their original position. This device would not of course set a clock right if the hand was so far wrong that it was not caught between the two arms of the pincers.

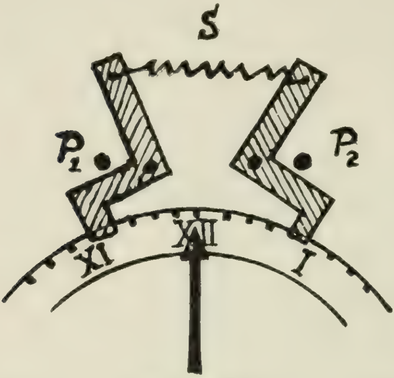


FIG. 221. — A SIMPLE METHOD OF SETTING A CLOCK ELECTRICALLY.

The so-called Bréguet system of synchronizing a clock is illustrated in Fig. 222. The mechanism is fairly complicated and requires an additional weight or spring to operate it. The three wheels R_1, R_2, and R_3 all have the same number of teeth. When the current is sent from the master clock the armature is pulled down and the pin at A released. The wheel R_1, which is driven by the weight or spring, makes one revolution before the pin is caught again. Wheels R_2 and R_3 also make one revolution. If the clock is fast, it is the pin on R_3 which acts on L and sets it right. If it is slow, it is the pin on R_2 which does the setting.

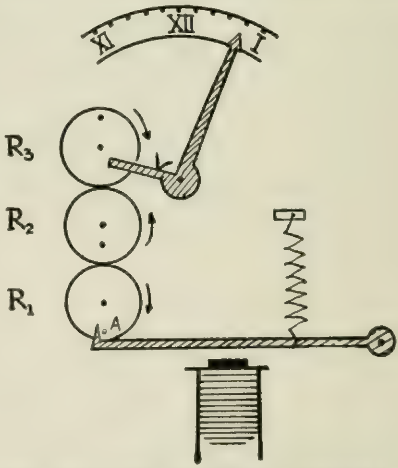


FIG. 222. — THE SO-CALLED BRÉGUET SYSTEM OF SYNCHRONIZING A CLOCK

Making contact. — Many times the expression "the clock makes contact" has been used just as if that was a very simple matter. As a matter of fact, it is a very troublesome affair. There

are three characteristics which this contact should have. It should be certain. It must be broken quickly when it is broken. It must derange the clock as little as possible. One device which fulfils these conditions fairly well is shown as a diagram in Fig. 223. This is essentially the arrangement used by Garnier of Paris. The star wheel *A* with five points is attached to the escape wheel arbor and thus turns in one minute. Contact is made every twelve seconds. The wheel *B* with the three arms C_1, C_2, and C_3 is turned by means of a separate weight or spring. As *A* turns, C_1 finally escapes and the wheel *B* turns until the arm C_2 strikes the point P_2. As it turns the point Q_1 strikes the lever *L* and moves it enough to make a certain contact at *K*. As soon as the point Q_1 leaves *L* the spring at *S* breaks the contact quickly. Since the contact maker is driven by a separate weight or spring, it deranges the clock mechanism as little as possible.

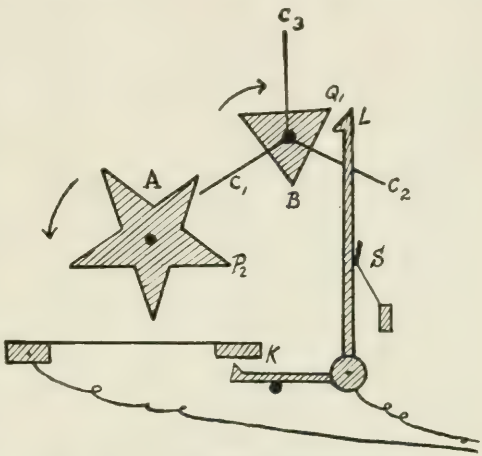


FIG. 223. — A CERTAIN CONTACT MAKER.

There are many other forms of contact makers which might be considered.

CHAPTER XIX

PRECISION CLOCKS — THEIR CONSTRUCTION, CARE, AND ACCURACY

The term "precision clock" is reserved for those extremely accurate timekeepers which are used in astronomical observatories, in watch factories, and in places where other timekeepers are tested and regulated. They are the most exact clocks which human ingenuity has been able to devise and construct. They are often called astronomical clocks or astronomical regulators, not in the sense that they indicate the time of some astronomical event, but because in an astronomical observatory, time as exact as possible is a necessity for certain observations. They are sometimes called simply regulators, but that word has been sadly misused. The high grade clocks, often found in jewelry stores and similar places where exact time is needed, are worthy of the name, but the word "regulator" has been put on cheap clocks, so that it has lost its force and meaning. This chapter is devoted to the history, care, and accuracy of precision clocks. Something will also be said about regulators in the correct use of that term.

Precision clocks and their makers. — Precision clocks are not numerous. There are probably not more than a very few thousand in existence in the whole world and yet, in the last analysis, they keep the time of the world, for all timekeepers of lesser accuracy are set to their indications. Among the makers of precision clocks at the present time may be mentioned:

The E. Howard Clock Co. of Boston, Mass.

E. Dent & Co., Ltd., 61 Strand, London, England.

L. Leroy & Cie., 7 Boulevard de la Madeleine, Paris, France.

Clemens Riefler, Karlsplatz 29, Munich, Germany.

In the chapter on the "History of Watchmaking in America," the history of the E. Howard Clock Co. will be given. One of their astronomical regulators is pictured in Fig. 224. The pendulum has mercury compensation and there are two jars instead of one, so that the response to a change in temperature will be more rapid. Such has been the accuracy of these clocks that they are in use in many observatories in the United States and places where exact time is desired.

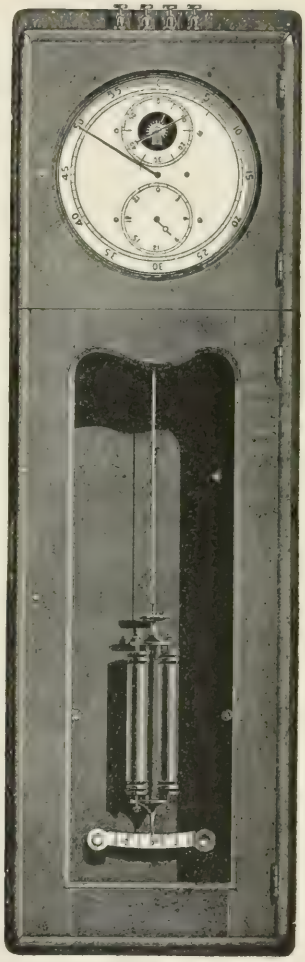


FIG. 224. — AN ASTRONOMICAL REGULATOR, BY THE E. HOWARD CLOCK CO.

In the chapter on "Modern European Watchmakers," the history of the firm E. Dent & Co. will be given. In 1871 this firm constructed the standard clock for the Greenwich Observatory. This clock was placed on the north wall of a basement where the temperature is remarkably uniform. The clock has barometric compensation.

More will also be said about the firm L. Leroy & Cie. in the chapter on "Modern European Watchmakers." One of his precision astronomical clocks is pictured in Fig. 225. It is inclosed in an air-tight case and has a nickel-steel alloy pendulum.

The firm Clemens Riefler, of Nesselwang and Munich, Germany, has been in existence since 1841, and they make primarily mathematical instruments and precision clocks. These clocks differ somewhat from the precision clocks of other makers. They have the escapement which

leaves the pendulum entirely free, patented by Sigmund Riefler (D. R. Patent No. 50739) and the nickel-steel alloy pendulum (D. R. Patent No. 100870). One of these clocks in its air-tight case is pictured in Fig. 226. A nickel-steel pendulum of the more usual form is shown in Fig. 227. It consists of a nickel-steel rod and a lens-shaped pendulum bob which rests at its center on a hollow tube of aluminum. This tube is only a few inches long and rests upon the regulating nut. The change in length of the nickel-steel rod for a change in temperature is so slight that it can be compensated by these few inches of aluminum. The earlier Riefler clocks had mercury compensation, the patent being D. R. Patent No. 60059. The escapement which leaves the pendulum entirely free is peculiar to this clock. Two views of it are given in Figs. 228 and 229. The pendulum is attached by means of two small pendulum springs i and i to the rocking top. This has two knife edges c, c which rest upon agate plates P, P. The escapement consists of two escape wheels. The outer one allows the tooth to escape while the inner one gives the impulse. The impulse is given to the pendulum in a unique manner. Soon

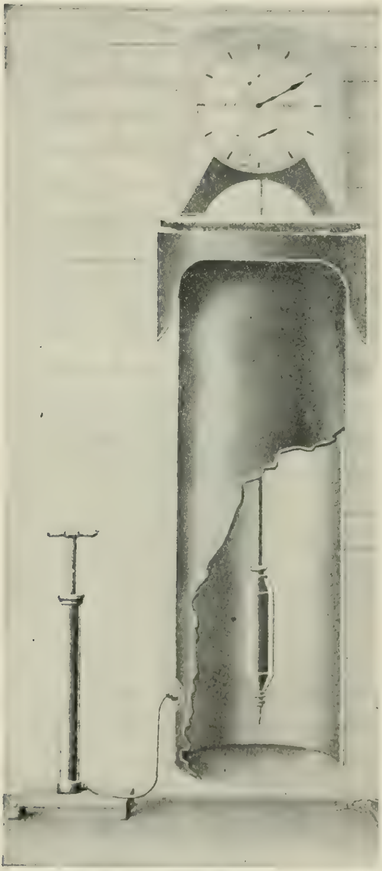


FIG. 225. — A PRECISION ASTRONOMICAL CLOCK, BY L. LEROY & CIE.

after the pendulum passes the position of rest, a tooth is allowed to escape and the escape wheel begins to turn. The inner impulse wheel moves the anchor slightly, and thus turns the rocking top, and bends the pendulum springs slightly. The impulse is thus given to the pendulum through the two small pendulum springs *i*, *i*. One difficulty with this escapement is that, due to a heavy jar, it may trip and run ahead several seconds.

It must not be supposed that all precision clocks are made or have been made by these four firms. If many observatories were visited, a fairly long list of names would be obtained. Many of these are no longer living. Others represent modern firms. This list would surely contain such names as Hohwü, Tiede, Winnerl, Frodsham, and Knoblich Hohwü was born in Schleswig in 1803. He settled in Amsterdam and died there in 1885. The standard clock at the Leyden Observatory, which has perhaps been as carefully investigated as any clock, was made by him. Joseph Thaddeus Winnerl was born in Styria in 1799. He settled in Paris and died there in 1886. The chief clock of the

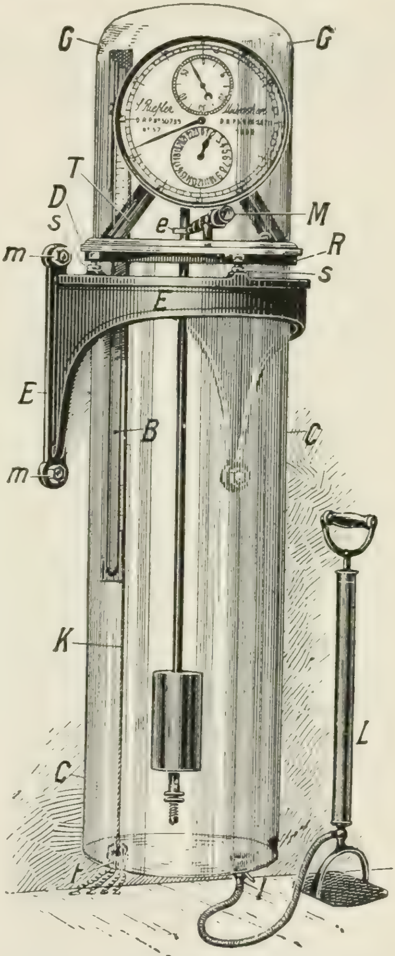


FIG. 226. — A PRECISION CLOCK IN AIR-TIGHT CASE, BY CLEMENS RIEFLER.

Paris Observatory is one of his clocks. The chief clock of the Berlin Observatory was made by Tiede of Berlin.

FIG. 227. — A NICKEL-STEEL PENDULUM, BY CLEMENS RIEFLER.

Tiede in 1865 was also the first to attempt to mount a clock in an air-tight case. At the famous Lick Observatory on Mount Hamilton, in California, there are two clocks by

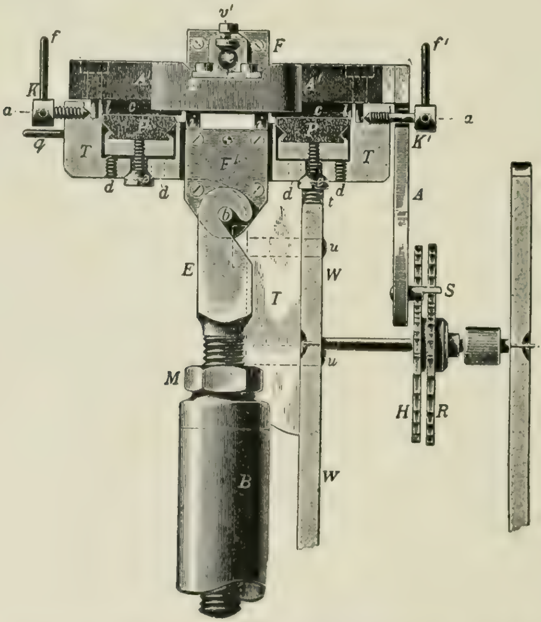


FIG. 228. — THE ESCAPEMENT OF A RIEFLER PRECISION CLOCK-SIDE VIEW.

Hohwü, one by Dent, one by Riefler, one by Frodsham, and one by Howard.

The general characteristics of precision clocks may now be stated. In the first place, they are all pendulum clocks.

In order to counteract changes in temperature, the pendulums either have mercury compensation or are nickel-steel alloy pendulums. The escapement is usually the dead-beat Graham anchor escapement. Occasionally the Denison three-legged gravity escapement is used and some have special escapements, as for example, those made by the firm Clemens Riefler. Many are inclosed in air-tight glass cases to keep the pressure the same. If so inclosed, they are electrically self-winding clocks; otherwise they are weight-driven. They are as simple as possible with no attachments of any kind except a device for making contact every second. It goes without saying that every part must be made with extreme care and thoroughness. Some clocks which are not inclosed in an air-tight case have a device attached to the pendulum for counteracting as far as possible the effect of changes in pressure. This sometimes takes the form of a little manometer tube partly filled with mercury. Otherwise the device is built on the aneroid barometer principle. One of these attachments, as used by the firm Clemens Riefler, is shown in Fig. 230. The cost of a precision clock is from $200 to nearly $1000 for the best that money can buy.

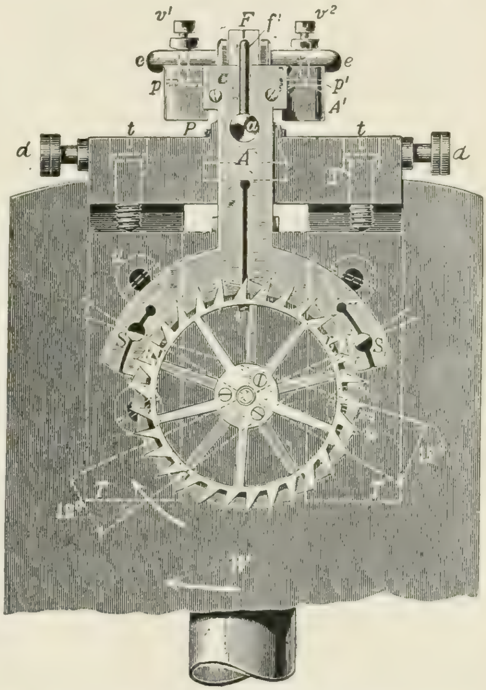


FIG. 229. — THE ESCAPEMENT OF A RIEFLER PRECISION CLOCK — FRONT VIEW.

The housing of precision clocks is almost as essential as care and proper design in their construction. There are four things which must be guarded against, namely, changes in temperature, changes in pressure, moisture, and jars. The clock, to be sure, is constructed, or can be, so as to be immune to the changes in temperature and pressure in large measure. The temperature changes are taken care of by using a mercury compensation or a nickel-steel alloy pendulum. The pressure changes are taken care of by a small attachment to the pendulum. Nevertheless, to get the best results a clock should not be exposed to changes either in temperature or pressure. If these four things mentioned above are to be completely guarded against, the clock must be placed in a clock vault. This is usually a brick or cement room in a deep basement or subcellar. Here the changes in temperature are usually small. Inside of this is another room or compartment. The sides and top may be of glass held in an iron framework or they may be made of hollow tile or brick. The temperature in the outer room should be kept constant. This is easily accomplished automatically by means of electric heaters and a thermostat. If the temperature gets a little high the current is turned off, if a little low, it is turned on again. There should not be a change in temperature of more than two degrees at most. The clocks, each in its air-tight case, should be mounted on piers going deep into the ground in the inner room. The air in the cases or in the inner room can be chemically dried. Housed in this way, jars, moisture, and changes in temperature and pressure are completely eliminated. But a clock vault is expensive and requires plenty of attention. There are

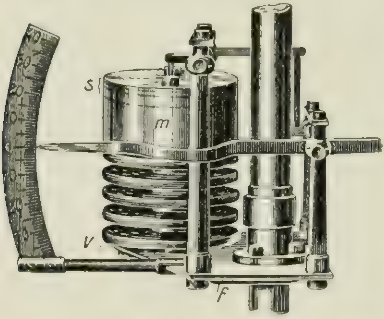


FIG. 230. — A PRESSURE COMPENSATING DEVICE FOR THE PENDULUM OF A PRECISION CLOCK.

only a very few of them in the United States. The clock vault at the United States Naval Observatory at Washington was described and pictured in Chapter I.

If a clock vault is out of the question, the next best way of housing a precision clock is to attach its case to a solid wall in a room where the temperature does not change much between day and night, summer and winter. It can then be surrounded by a big wooden box. This will prevent all sudden changes of temperature. This arrangement would eliminate most of the jars, the moisture, the changes in pressure, and most of the temperature changes. It would also be an inexpensive method of housing. Many precision clocks are simply fastened to a rigid wall in an ordinary case without any attempt whatever to guard against the four things.

If a clock is not housed in a clock vault the best results can be obtained by using a formula to compute its probable rate. These formulae contain at least four terms: the normal rate, the slow change with time, the effect of temperature, and the effect of pressure. Sometimes other terms are added, such as the effect of a difference in temperature between the top and bottom of the pendulum, terms involving higher powers of temperature and the like.

This paragraph is only for those who like Mathematics. Such a formula would look like this:

$$R = R_0 + a(T - T_0) + b(t - t_0) + c(p - p_0)$$

where R is the rate at a time T, a temperature t, and a pressure p. R_0 is the normal rate corresponding to a time T_0 and a temperature of t_0 and a pressure of p_0. Values are assumed for T_0, t_0, and p_0. Usually, average values for the period under consideration are taken. If, for example, the temperature changed between 64° and 70° during the three months of testing, t_0 would be taken as 67°. Each observation of R at a time T, temperature t, and pressure p now yields an equation with four unknown quantities, R_0, a, b, and c. Four observations would thus give their values, but the larger the number of observations the greater the accuracy. The reduction must then be made by the "method of least squares." After the values of R_0, a, b, and c have

been found, the most probable rate R for any time T and temperature t and pressure p can be computed. This will be illustrated a little later.

The accuracy of precision clocks. — We now come to a very interesting question. How accurate are precision clocks? They are the best timekeepers that man has devised. How closely will they keep time?

The accompanying table [1] gives the record of Riefler clock No. 56 for three months during 1901–2. The clock is at the Case Observatory in Cleveland. It is fastened to the wall of a constant temperature room. It is an air-tight case and the pressure was maintained at 673 mm. for the three months. The clock was thus housed in the best way. The first column gives the dates when the clock error was determined; the second gives the different values of error; the third gives the daily rates; the fourth the departure of each rate from the average of all of them.

Date — 1901–2	Clock Error	Daily Rate	Mean Daily Rate Minus Daily Rate
Dec. 17	− 13.58^s	+ 0.097^s	0.019^s
20	− 13.29^s	.112^s	.004^s
21	− 13.18^s	.094^s	.022^s
Jan. 17	− 10.63^s	.103^s	.013^s
19	− 10.41^s	.134^s	.018^s
25	− 9.62^s	.100^s	.016^s
27	− 9.42^s	.100^s	.016^s
28	− 9.31^s	.114^s	.002^s
30	− 9.09^s	.135^s	.019^s
Feb. 4	− 8.41^s	.135^s	.019^s
10	− 7.59^s	.137^s	.021^s
15	− 6.89^s	.127^s	.011^s
Mar. 5	− 4.60^s	.117^s	.001^s
10	− 4.02^s	.137^s	.021^s
13	− 3.61^s	.098^s	.018^s
19	− 3.02^s		
		Mean daily rate + 0.116^s	Mean ± 0.015^s
			Max. 0.022^s

On December 17, 1901, the clock was 13.58^s fast and on March 19, 1902, it was 3.02^s fast. It had lost a little over ten seconds in about three months. The test of accuracy

[1] Charles S. Howe, "The Rate of the Riefler Sidereal Clock, No. 56," *Astronomical Journal,* No. 524, 1902.

is not, however, how little the clock lost but how constant the rate of loss remained. This is shown in the last two columns. The mean daily rate comes out 0.116^s (about a ninth of a second a day). The mean departure of the different daily rates from the mean of all of them is only $\pm 0.015^s$ and the largest departure is only 0.022^s. Thus, over a period of three months, the clock maintained its rate constant within about two hundredths of a second. Think of it! And De Vick's clock in 1360 kept time within two hours a day. This is a gain in accuracy of 360,000 times in less than six centuries.

The behavior of the Dent clock at the Greenwich Observatory[1] for a period of three months is given in the accompanying table. The temperature changes did not amount to more than 5° F. during the three months. There is an automatic device for correcting for pressure changes, but no air-tight case.

GREENWICH CLOCK

1904		Mean Daily Rate	Deviation from Mean
Feb.	8–12	0.110^s	0.078^s
	12–15	$.123^s$	$.065^s$
	15–19	$.135^s$	$.053^s$
Mar.	1–3	$.180^s$	$.008^s$
	9–16	$.203^s$	$.015^s$
	16–18	$.235^s$	$.047^s$
	18–22	$.180^s$	$.008^s$
	22–25	$.206^s$	$.018^s$
	27–30	$.156^s$	$.032^s$
Apr.	30– 1	$.180^s$	$.008^s$
	1– 5	$.191^s$	$.003^s$
	5–13	$.207^s$	$.019^s$
	13–16	$.223^s$	$.035^s$
	16–19	$.240^s$	$.052^s$
	19–22	$.227^s$	$.039^s$
	24–29	$.192^s$	$.004^s$
May	1– 4	$.220^s$	$.032^s$
	4– 7	$.207^s$	$.019^s$
	7–12	$.158^s$	$.030^s$
		Mean 0.188^s	Mean $\pm 0.030^s$ Largest 0.078^s

[1] Thomas Lewis, "The Clocks of the Greenwich and U. S. Naval Observatories," *Science*, N. S., Vol. XXV, No. 648, p. 868, 1907.

U. S. NAVAL OBSERVATORY, WASHINGTON

RIEFLER SIDEREAL CLOCK, NO. 70

1904	Daily Rate	Deviation from Mean	Pressure mm.	Temp. C.	Computed Rate	Observed Minus Computed
Feb. 8–11 . .	+ 0.019s	0.003s	631.0	28.3	+ 0.009s	+ 0.010s
11–15 . .	− 0.014s	.030s	631.5	28.5	− 0.006s	− 0.008s
15–20 . .	+ 0.005s	.011s	631.5	28.3	− 0.002s	+ 0.007s
Mar. 1– 4 . .	− 0.026s	.042s	631.0	28.2	− 0.012s	− 0.014s
4– 9 . .	− 0.010s	.026s	631.0	28.2	− 0.016s	+ 0.006s
9–16 . .	− 0.022s	.038s	631.5	28.1	− 0.018s	− 0.004s
16–18 . .	− 0.043s	.059s	631.0	28.1	− 0.022s	− 0.021s
18–22 . .	− 0.022s	.038s	631.0	28.0	− 0.021s	− 0.001s
22–25 . .	− 0.029s	.045s	631.0	28.0	− 0.024s	− 0.005s
25–28 . .	+ 0.002s	.014s	631.0	27.7	− 0.014s	+ 0.016s
28–34 . .	− 0.007s	.023s	631.0	27.7	− 0.018s	+ 0.011s
Apr. 3– 5 . .	+ 0.017s	.001s	631.0	27.4	− 0.009s	+ 0.026s
5–13 . .	+ 0.002s	.014s	631.0	26.9	+ 0.014s	− 0.012s
13–16 . .	+ 0.026s	.010s	631.0	26.5	+ 0.021s	+ 0.005s
16–19 . .	+ 0.034s	.018s	631.0	26.3	+ 0.027s	+ 0.007s
19–22 . .	+ 0.002s	.014s	631.0	26.4	+ 0.020s	− 0.018s
22–31 . .	+ 0.029s	.013s	631.0	25.0	+ 0.077s	− 0.048s
May 1– 4 . .	+ 0.113s	.097s	631.5	24.3	+ 0.103s	+ 0.010s
4– 7 . .	+ 0.082s	.066s	631.0	24.1	+ 0.109s	− 0.027s
7–12 . .	+ 0.161s	.145s	631.0	24.0	+ 0.109s	+ 0.052s
	Mean + 0.016s	Mean ± 0.035s				Mean ± 0.015s

The accompanying table [1] gives the behavior of Riefler clock No. 70 at the Naval Observatory at Washington for the same period. The clock is in a clock vault, but the temperature varied nearly 5° C. The pressure was practically constant. This table also illustrates the use of a formula. The mean daily rate comes out + 0.016s and the mean deviation of rate from the average of all, ± 0.035s. It thus falls just a little short of the Greenwich clock for this period, its deviation being ± 0.030s. A formula was computed from these twenty values of rate. Since the pressure changes were so slight, the pressure term in the formula

[1] W. S. Eichelberger, "Clocks — Ancient and Modern," *Science*, N. S., Vol. XXV, No. 638, p. 441, 1907.

was omitted. T_0 was assumed to be March 29.0 and t_0 27.0. The formula is Rate = $+ 0.0161^s - 0.00103^s$ (T − March 29.0) $- 0.0456^s (t - 27.0°)$.

From this formula the computed rates in the sixth column were determined. The seventh column gives the observed rate minus the computed. It will be noticed that the average of these is $\pm 0.015^s$. The use of a formula thus just about doubled the accuracy, for without it the mean deviation comes out $\pm 0.035^s$ and with it, $\pm 0.015^s$.

As a further example, the formula for the clock Knoblich 1770, at the Bothkamp Observatory [1] in Germany is here given. This clock has no air-tight case, but a manometer has been added to the pendulum to take care of pressure changes. An additional term here appears in the formula

Rate = $- 0.0676^s + 0.0440^s (T - 1910) + 0.0094^s \times t - 0.0016^s (p - 750$ mm.) $- 0.031^s \times$ Diff. of temp. (above − below.)

Regulators. — This chapter will close with a few remarks about regulators in the correct use of that term. Most good jewelers have a high grade clock which they use for testing and regulating the watches and clocks which are brought to them to be cleaned and repaired. There are also many places where a good timekeeper is a necessity. All such clocks are worthy of the name of regulators. Practically all the clock factories make several styles of high grade clocks which may serve as regulators. They are nearly always pendulum clocks. Some of them have mercury compensation or gridiron pendulums. A word of caution is necessary here. Not all are gridirons which appear to be. Often the pendulum consists of a wood rod and a large zinc bob. An alloy pendulum is very rare. The escapement is usually the Graham dead-beat anchor. The Denison three-legged gravity is sometimes found. Regulators are

[1] K. Schiller, "Untersuchung über den Gang der Hauptuhr der Bothkamper Sternwarte Knoblich, 1770," *Astronomische Nachrichten*, No. 4734, Band 198, p. 89, 1914.

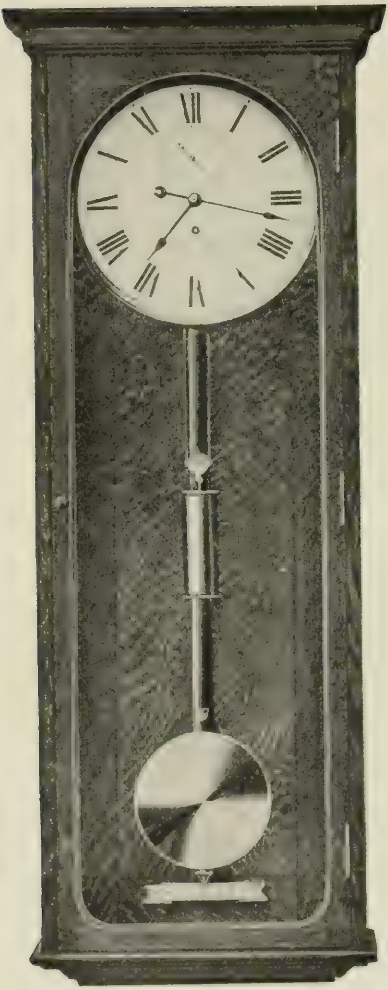


FIG. 231.—A REGULATOR AS MADE BY THE SETH THOMAS CLOCK CO.

practically all weight-driven. In Fig. 231 is illustrated a regulator as made by the Seth Thomas Clock Co. of Thomaston, Conn. It is weight-driven and has a dead-beat escapement, and a pendulum consisting of a wooden rod and a zinc bob.

A good regulator, well taken care of, should keep time within ten or fifteen seconds a month. There are two points in connection with a regulator which are frequently overlooked. They are often hung on a thin partition where every slam of the door causes considerable jar. It goes without saying that they should be hung on as firm a support as possible. They are also often placed near the show window, where they can be seen from the street and then at certain times of day the sun shines on them. This is almost sure to be fatal to accuracy.

CHAPTER XX

THE HISTORY OF CLOCKMAKING IN AMERICA

There are three distinct periods in the history of clockmaking in America. The first extends from the earliest colonial times until about 1800. It was the era of individual effort. Each clockmaker made but a few clocks, entirely with hand tools, and they were usually not exactly alike. The second period extends from 1800 to almost 1860. Machine methods made their appearance and numerous clock factories came into existence. The number of different kinds of clocks made during this period was, however, extremely small. There were not many more than a half dozen varieties. The third period is the modern period and extends from 1860 to the present day. Its three great characteristics are (1) the use of factory methods only, (2) a small number of clock factories but most of them large ones, and (3) an enormous variety in the output.

Clockmaking during colonial times. — The first clockmakers in this country came from England and Holland. They had learned their trade and gained their experience before coming, they brought their tools with them, and they made the same kinds of clocks which they had been making before they came. Later many clockmakers learned their trade here. Mrs. N. Hudson Moore, in her very interesting volume, *The Old Clock Book*, mentions William Davis and Everardus Bogardus as the two first. William Davis arrived in Boston in 1683. His family was large and his amount of money small. One David Edwards became surety that they would not become charges upon the town. Everardus Bogardus was busy at clockmaking in New York City in 1698.

As time passed the number of clockmakers of course increased, but it is impossible to ever secure a complete and

accurate list of them all (see Appendix V). Many made but a few clocks and they have all disappeared. Many never put their names on their clocks. The custom of putting a so-called "clock paper" inside a clock did not arise until after 1800. Many never advertised in papers or became generally known in any way. Those names which are found in lists have been secured by very patient and almost unending search through old newspapers, old letters, town records, genealogies, and the like. In many instances their clocks are still in existence.

These have all been called clockmakers, although they usually imported and repaired clocks and watches also. In short, they usually carried on a general business and bought, sold, imported, made, and repaired all kinds of timekeepers. Some probably only repaired and dealt in clocks and should not be considered clockmakers at all. But it is almost impossible to make distinctions and their names have crept into the lists. Generally, clocks were only made when ordered and in accordance with the wishes of the would-be purchaser.

Some of the advertisements in old newspapers make interesting reading. In the *New York Mercury* for January 3, 1757, Thomas Perry advertises as follows:

> Thomas Perry, watch-maker, from London, at the sign of the Dial, in Hanover Square, makes and cleans all sorts of clocks and watches in the best manner, and at a most reasonable rate. He has a parcel of good gold and silver watches, new and second-hand, very cheap, also silver and metal chains, silver and pinchbeck seals, silk strings, glasses, keys, straps, &c. He will import, if bespoke, good warranted clocks, at £14, they paying freight and insurance, and clocks without cases, for £10. Said Perry has just imported a parcel of very good watches, which he will warrant.

In the May 1, 1758, number of the same paper John Ent advertises thus:

> John Ent, Clock, and Watch-maker, at the Sign of the Dial, has moved to the House of Mr. John Wright, Watch-maker, in

Bayard street, where he continues to make and repair in the newest Manner, All Sorts of Clocks and Watches, whether repeating, horizontal, or the plain kind. Gentlemen and Ladies that are pleased to honour him with their Employ may depend on the greatest care and Dispatch imaginable.

The clocks were all made individually, by hand, using only hand tools. Thus no two clocks would be exactly alike, although the clocks made by any one clockmaker would naturally show great similarity. The wishes of the purchaser could also be followed. Most of the clocks were grandfather clocks. This was the prevailing kind in England at the time. Some had mahogany or walnut case, works made of cast brass, and ran for eight days. The cheapest ones were in painted pine cases, had wooden works, and ran for only one day. After the war of the Revolution, the condition of the country made the demand for cheap clocks greater, so that just before 1800 cheaper rather than better clocks were the rule. Some hang-up clocks or wag-on-the-walls were also made. These looked like the works of a grandfather clock without the case. In fact, many of them were simply that. It was often the custom to purchase the works from some clockmaker in a city and then to have a local cabinet maker construct the case. After the works were purchased they were often hung on the wall without having the case made and thus became wag-on-the-walls. Occasionally a more ambitious clockmaker might attempt to make one of the more elaborate mantel clocks in the English or French style, but nearly all of these were imported. A very few tower clocks were also made. Thus it is almost correct to say that up to nearly 1800 the only clocks made in this country were grandfather clocks and some hang-up clocks and that they were all made by hand.

Old grandfather clocks are not very rare. Nearly every one knows of five or six or more in the possession of friends or neighbors. In Figs. 232 and 233 are illustrated two grandfather clocks of American make prior to 1800. (Three

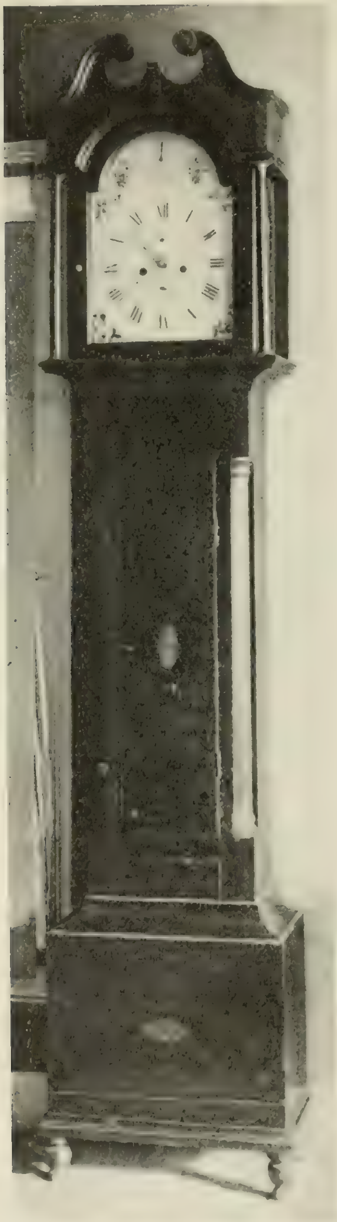


FIG. 232.—AN AMERICAN GRANDFATHER CLOCK, BY WILLIAM CLAGGETT.

(Boston Museum of Fine Arts.)

FIG. 233.—AN AMERICAN GRANDFATHER CLOCK, BY JOSHUA WILDER.

(Boston Museum of Fine Arts.)

FIG. 234.—AN AMERICAN GRANDFATHER CLOCK, BY DANIEL PORTER.

more are illustrated in Figs. 234, 235, and 236.) It will be noticed in connection with both of them how closely they resemble the English grandfather clock made during the same period. They are in the Museum of Fine Arts in Boston, loaned by Mr. George W. Brown of Boston. The first (Fig. 232) is by William Claggett of Newport and dates from about 1720. It has a pine case with a circular green glass disc for showing the pendulum and a brass dial. It is 2.36 meters high. William Claggett is ranked as a good clockmaker. He was born in 1696, made freeman at Newport in 1726, and died at Newport in 1749. There are several of his clocks in existence. The other is by Joshua Wilder of Hingham and dates from just before 1800. It has an inlaid mahogany case with brass mounts and is 2.40 meters high.

Williamstown, Mass., also had its colonial clockmaker. According to the Registry of Deeds, Daniel Porter purchased his house and lot on Main Street February 14, 1799. It was located "10 rods west of a well with a pump in it and a few rods west of the college." He was then spoken of as clockmaker. Clockmaking could not have been a paying profession, for he mortgaged his house at once for the stupendous sum of $146. Three of his clocks are still running in or near Williamstown. They are eight-day clocks, with brass works and handsome cases. One of them, in the possession of Miss Eleanor Duncan, is pictured in Fig. 234. All of these facts have been added about this clockmaker not because he is particularly famous but simply because it is typical of the way clocks were made during colonial times.

These early grandfather clocks were not considered very valuable at the time. According to the inventories of personal property the earliest were usually valued from 6s. to £20.

The coming of the clock factories occurred between 1800 and 1860 and they have made one state in particular, Connecticut, famous. To start at the very beginning of the story of clockmaking by factory methods, one must go

back to Thomas Harland. He arrived in Boston in 1773 in the ship from which the tea was thrown overboard in Boston Harbor. He proceeded at once to Norwich, Conn., and started in business. His advertisement in *The Norwich Packet* for December 9, 1773, is as follows:

"Thomas Harland, Watch and Clock-maker from London, Begs leave to acquaint the public that he has opened a shop near the store of Christopher Leffingwell, in Norwich, where he makes in the neatest manner and on the most approved principles, horizontal, repeating, and plain watches in gold, silver, metal, or covered cases. Spring, musical, and plain clocks; church clocks; regulators, etc. He also cleans and repairs watches and clocks with the greatest care and dispatch, and upon reasonable terms.

"N. B. Clock faces engraved and finished for the trade. Watch wheels and fusees of all sorts and dimensions, cut and finished upon the shortest notice, neat as in London, and at the same price."

Harland must have been a particularly fine clockmaker, for his fame spread far and wide and many apprentices came to him, some of whom became well known later. Thomas Harland died in 1807. The Harland family is one of the old families of Connecticut and there are many descendants. A grandfather clock made by Thomas Harland is shown in Fig. 235. It is now in the Metropolitan Museum of Art in New York City.

The one apprentice of Harland's destined to become the most famous of all was Eli Terry, who was born in East Windsor, now known as South Windsor, Conn., April 13, 1772. His parents were Samuel and Huldah Burnham Terry, and he was the oldest of ten children. His father was a direct descendant in the fourth generation of the Samuel Terry who came to Springfield, Mass., in 1654. Eli Terry commenced his apprenticeship very early in life (1786) and at the age of twenty had made his first wooden clock. This clock is still in existence and is pictured in Fig. 236. According to the *Hartford Courant* for November 19, 1896, the personal property of James Terry of Winsted, Conn.,

FIG. 235.—AN AMERICAN GRANDFATHER CLOCK, BY THOMAS HARLAND.
(The Metropolitan Museum of Art, New York.)

FIG. 237.—A GRANDFATHER CLOCK BY THOMAS & HOADLEY.
(Essex Institute, Salem, Mass.)

Copyright 1911 by Frederick A. Stokes Company.

FIG. 236. — ELI TERRY'S FIRST CLOCK.
(Reprinted by permission from *The Old Clock Book* by N. HUDSON MOORE.)

president of the Eagle Lock Company, had just been sold at auction. Among his possessions was this clock which was finally sold to his grandson, E. C. Terry, for $1000.

In 1793 Eli Terry went to Northbury as a part of Plymouth[1] was then called, and began making a few hang-up clocks. He was shortly married to Eunice Warner of that place; in fact, Terry was twice married and had a family of eleven children, nine by his first wife and two by his second. In 1793 Terry was using only hand tools and commencing one or two clocks at a time. By 1800 he had conceived the idea of using water power to drive the tools and water was conveyed from "Niagara Brook" across the street to his shop. He had perhaps one or two men or boys to help him and was commencing ten to twenty clocks at a time. The first clock factory in America had now come into existence. This is the first small beginning of the tick of the Connecticut clock which was destined to be heard round the world.

In 1807 he sold his water-power to Heman Clark, one of his apprentices, and bought power and an old mill at Greystone (in the southeast portion of Plymouth). Seth Thomas

[1] The town of Plymouth was made distinct as the society of Northbury in 1780. It was then incorporated with the Society of Westbury as Watertown. In 1795 Northbury was set off by itself and called Plymouth.

and Silas Hoadley now joined him and they shortly began business under the firm name of Terry, Thomas, and Hoadley. They now began the construction of four thousand clocks commencing five hundred at a time. They were ridiculed and even jeered at for so foolish and gigantic an undertaking. These clocks were peddled all over the country. Eli Terry himself often went on horseback for long trips carrying as many of his clocks as he could. It was usually only the works which were taken. The people who purchased them depended upon local cabinet makers to make the cases or they were used as wag-on-the-walls. These clocks were wooden (grandfather) clocks, running thirty hours, and having seconds pendulums. They sold, dial and hands included, for $4. The four thousand clocks were finished in three years, all sold, and at a good profit.

In 1810 Eli Terry sold out to Thomas and Hoadley, who continued in business at Greystone, and removed to Plymouth Hollow. In Fig. 237, on page 349, is illustrated one of these grandfather clocks made by Thomas & Hoadley. It is in the Essex Institute at Salem, Mass. It has a hard wood case and a painted dial. It is a one-day clock with wooden works.

Eli Terry was an inventive genius as well as a practical man of affairs. For a number of years prior to 1810 he had been thinking about and experimenting with the "shelf clock." By a shelf clock is meant a clock, two or three feet high, to be placed on a shelf, originally with a half-seconds pendulum, and the weight cords running over pulleys in the top of the case so as to give the weights as long a fall as possible. It is the well-known colonial shelf clock so much sought after by those interested in antiques at the present day and needs no further definition. Perhaps Terry should be considered the inventor of the shelf clock. It is impossible to say when he made the first one. It was certainly considerably before 1810. At that time shelf clocks were being made at two other places in Connecticut, at Salem Bridge, now Naugatuck, and at Plym-

outh Hollow, now Thomaston. These were eight-day clocks with brass works, while Terry was experimenting with one-day clocks with wooden works. If these two manufacturers had borrowed ideas from Terry or Terry from them, it is impossible to say. The Massachusetts form of shelf clock was, of course, already in existence, for the Willards and others had made them at least as early as 1790. But their form as we shall see later was radically different. How much Terry knew about these clocks it is impossible to say. Terry made several different forms, sometimes making several hundred clocks of a certain pattern, but he was not pleased with any one of them. Finally, in 1814, he devised and patented what completely satisfied him and what he called his "perfected wood clock." It was this clock which was made by the tens, yes, hundreds of thousands, that drove out all other clocks for a time, brought fame to the state of Connecticut, and made Eli Terry and many others rich and prosperous. Chauncey Jerome mentions this in his rather pathetic but interesting little book, *History of the American Clock Business for the Past Sixty Years and Life of Chauncey Jerome, written by himself.* It was written in 1860, when Jerome was sixty-seven years old. He had taken part in and seen the full development of clockmaking from the beginning. In one place he says: "Mr. Eli Terry (in the year 1814) invented a beautiful shelf clock made of wood which completely revolutionized the whole business. The making of the old-fashioned hang-up wood clock, about which I have been speaking, passed out of existence. This patent article Mr. Terry introduced was called the Pillar Scroll Top Case. The pillars were about twenty-one inches long, three quarters of an inch at the base, and three eighths at the top - resting on a square base, and the top finished by a handsome cap. It has a large dial eleven inches square, and tablet below the dial seven by eleven inches. This style of clock was liked very much and was made in large quantities, and for several years. Mr. Terry sold a right to manufacture them to Seth Thomas, for one thousand dollars, which was thought

to be a great sum. At first, Terry and Thomas made each about six thousand clocks per year, but afterwards increased to ten or twelve thousand. They were sold for fifteen dollars apiece when first manufactured. I think that these two men cleared about one hundred thousand dollars apiece up to the year 1825."

A portrait of Eli Terry is shown in Fig. 238. In Figs. 239 to 242 are shown four of these perfected wood clocks. The first is in the possession of Harvard College; the second is at Essex Institute, Salem, Mass., the third belongs to Professor John C. Duncan, Wellesley, Mass.; the fourth is the property of James Vint & Son, 34 North Pearl Street, Albany, N. Y. The second one is by Seth Thomas, the rest are Terry clocks. Figs. 242 and 243 are used as the frontispiece of this book.


FIG. 238. — ELI TERRY (1772-1852).

It will be seen that Jerome's description is entirely correct. The dials were of painted wood about eleven inches square. The spandrels were often roses painted in gilt and several strongly contrasting colors. The hours on the dial were sometimes Roman numerals (I, II, etc.) and sometimes figures (1, 2, 3, etc.). The door of the clock case contained a piece of plain glass covering the dial and below this a painted glass panel about eleven inches by seven. Birds, flowers, fruit, or a village or domestic scene were usually depicted on the panel. The case was generally of mahogany, rarely of walnut. It was usually not solid mahogany, but veneered. The pillars were small, round, slightly tapering, and separate from the clock case. The clock usually had feet, but these have occasionally been broken off so that they now appear with-

FIG. 239. — A TERRY PERFECTED WOOD SHELF CLOCK.

FIG. 240. — A SETH THOMAS SHELF CLOCK AT ESSEX INSTITUTE IN SALEM, MASS.

out them. A close examination will often show that they once existed. The top had metal ornaments, or wood ornaments, or was sometimes plain. The case had a key and around the keyhole was a diamond-shaped ivory, bone, or metal inlay. The works were of wood, the escape wheel of brass. The escapement was the anchor of the so-called American form (see Fig. 46) and the pendulum rod was of iron. They were striking clocks, using the count wheel, and they had half-seconds pendulums.

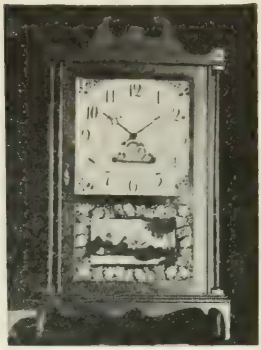


FIG. 241. — A TERRY SHELF CLOCK.

As the years passed and these shelf clocks were made by other manufacturers as well as Terry and Thomas, slight changes in their appearance took place. The dimensions remained the same, eleven by eleven for the dial and eleven by seven for the painted panel. The columns became larger and were attached to the clock case. They were sometimes carved and sometimes painted black and ornamented with gilt stenciling. The top ornaments were usually omitted. Instead the top piece was sometimes carved and sometimes decorated with gilt stenciling. The feet were larger and often omitted entirely. In Fig. 243 one of these later shelf clocks is shown. The maker is unknown, as the clock paper has been destroyed. The painted panel is also a modern restoration, as the original was broken.

Of the shelf clocks made before 1814 but very little is known. There are almost none in existence and it is almost impossible to be sure of those which seem to be of so early a date. And yet Eli Terry made several hundred, if not a thousand of them, and the other two makers must have made some. One form had no dial. The numbers were painted on the glass in the door of the clock case. Another form had the crutch and pendulum rod in front of the dial.

In 1814, when Eli Terry commenced to make his improved wood clocks in great numbers, he began to teach two of his sons, Eli, Jr., and Henry, the clock business. Eli, Jr., was then but fifteen years old, as he was born June 25, 1799, and Henry was still younger. The factory was at Plymouth Hollow, near Terry's Bridge. When twenty-five years of age, Eli Terry, Jr., built a factory for himself on the Pequabuck and began the manufacture of clocks. He died when he was only forty-two, but he had already amassed a fortune and the village where he lived was called Terryville in his honor.

Henry Terry continued in the original factory, but finally gave up clock making and turned his attention to woolen goods. He died in 1877. Another son of Eli Terry, namely. Silas Burnham Terry, was also a clockmaker. He had a shop at the junction of the Pequabuck and Poland rivers in 1831. He was an inventive genius, but not a practical man of affairs. He invented several kinds of clocks and several improvements in clocks, but they did not prove a success. For a time he was in the employ of William L. Gilbert at Winsted, Conn., and of the Waterbury Clock Co. Eventually he and his sons organized the Terry Clock Co., of which he was the head at the time of his death in May, 1876.

Eli Terry died at Terryville, February 24, 1852. Although his fame and fortune were made with the improved wood shelf clock, he also made fine clocks with brass works and even tower clocks.

An interesting little pamphlet by Henry Terry, Waterbury, Conn., 1872, called *American Clockmaking, Its Early History*, gives much information concerning the Terry family, as does also the *History of the Town of Plymouth*, by Francis Atwater (The Journal Publishing Company, Meriden, Conn., 1895).

The second great figure in the history of clockmaking in Connecticut is that of Seth Thomas, whose portrait is shown in Fig. 244. He was born in Wolcott, Conn., August 19, 1785, the son of James and Martha Thomas. Very early in life he was apprenticed to a carpenter and worked for

several years on houses and barns in Plymouth. When twenty-two years of age, with almost nothing except his tools, he joined Eli Terry and Silas Hoadley at Greystone. Soon the firm of Terry, Thomas & Hoadley was busily engaged in making clocks. His part was the joiner work. That is he made the cases and put the clocks together and fitted them in their cases. As has already been narrated, Terry sold out his interests in this firm in 1810. Two years later Thomas also sold to Hoadley and went to Plymouth Hollow. Here he began clockmaking on his own account and was successful from the start. In 1814 when Terry invented the improved wood clock, he purchased the right to make the patented article for $1000 and was soon making as many clocks as Terry himself. Although not an inventive genius he was very successful in business and made money rapidly. He remained in business in the same place and on March 31, 1853, the Seth Thomas Clock Company was organized with a capital of $75,000. He died January 29, 1859. He had been twice married and had had nine children. Soon after his death that part of Plymouth where the factory was located was called Thomaston in his honor.

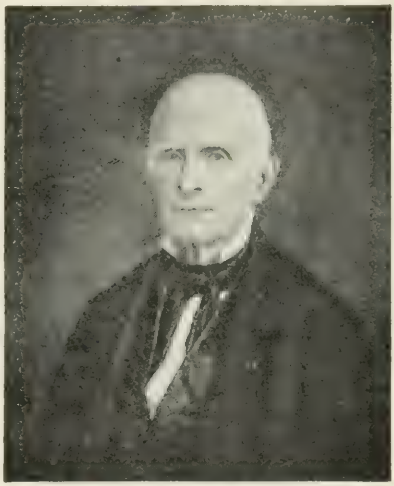


FIG. 244. — SETH THOMAS (1785-1859).

Although not a famous clockmaker, the third member of the original firm, Silas Hoadley, deserves passing mention. He was born at Bethany, Conn., in 1786. At an early age he too was apprenticed to his uncle, Calvin Hoadley, to learn the carpenter's trade. When barely past twenty-one he joined Terry and Thomas at Greystone. When Thomas

sold out his interests in 1812, he was the only remaining member of the firm. He continued to make clocks until 1849 at the old stand and was quite successful. He then retired and died at Plymouth December 28, 1870.

Chauncey Jerome is the third great name in the history of clockmaking in Connecticut. His portrait is shown in Fig. 245. He was born in Canaan, Litchfield County, Conn., June 10, 1793. His father was a blacksmith and wrought-nailmaker. He was poor but industrious and respectable, and had a family of six children, three boys and three girls. In 1797 the family moved to Plymouth and at the age of nine Chauncey was already making nails in his father's shop. His father died in 1804 and this caused the breaking up of the family. At first he worked on a farm, then at the age of fifteen he went to learn the trade with a house carpenter. He was to receive board and clothes for his services. At the age of eighteen he made a bargain with the man that, if he could have the four winter months each year for himself, he would furnish his own clothes. His first job was at Waterbury, where he began to make dials for grandfather clocks. When twenty-one years of age he married Salome Smith and moved to Farmington. He returned in a year and went to work for Eli Terry. This was in 1816 and Terry was just commencing the manufacture of his new patent improved wood shelf clock in large quantities. After a year or two Jerome started in a small way to work for himself. He was fairly successful, but it was not very profitable.

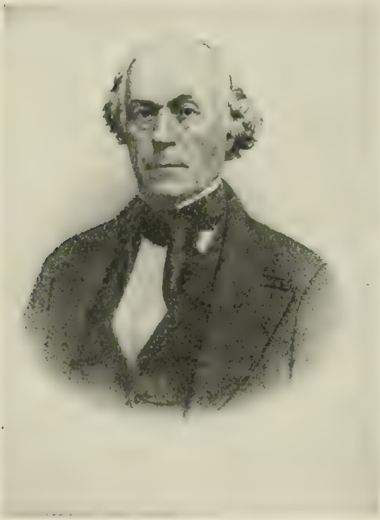


FIG. 245. — CHAUNCEY JEROME.

In 1821 he moved to Bristol. It is interesting to note in this connection that he sold his house in Plymouth to Eli Terry for 100 clock movements and purchased his house in Bristol for 214 movements. Clock movements were being used almost like currency at this time in this part of Connecticut. In 1824 the firm of Jerome and Darrow was formed. This consisted of Chauncey and his brother Nobles Jerome and Elijah Darrow. They began making a clock very similar to that which was being made by Terry and by Thomas.

In 1825 came one of the chief events in his life. It was the invention of the bronze looking-glass clock. Jerome, in his book, which has already been mentioned, has this to say about it in two different places: "In the year 1825 the writer invented a new case, somewhat larger than the Scroll Top, which was called the Bronze Looking-glass Clock. This was the richest looking and best clock that had ever been made, for the price. They could be got up for one dollar less than the Scroll Top, yet sold for two dollars more. . . . During which time I invented the Bronze Looking-glass Clock, which soon revolutionized the whole business. As I have said before, it could be made one dollar less and sold for two dollars more than the patent case; they were very showy and a little larger." The original clock was about six inches taller than the Terry patented clock. The door of the case consisted of two parts. At the top was a piece of plain glass to cover the dial and below that was the bronze looking-glass. The movement was almost exactly the same as that in the Terry clock. It is a question if these clocks seem any more pleasing than the original Terry patent. Nevertheless, at that time they were the latest fashion and were the ones sought after to the practical exclusion of all others. Even Terry and Thomas had to make them to the neglect of their own forms. Between the years 1825 and 1837 Jerome was very prosperous, made perhaps more clocks than any other factory in Connecticut, and amassed a considerable fortune.

Later the bronze looking-glass was not always used even

FIG. 246. — A SETH THOMAS CLOCK.

FIG. 247. — A BRONZE LOOKING-GLASS CLOCK.
(Essex Institute, Salem, Mass.)

by Jerome himself and many other manufacturers did not use it. Its place was taken by a painted glass panel. Sometimes the door consisted of three parts, a piece of plain glass to cover the dial, below that a bronze looking-glass, and below that a small painted glass panel. Sometimes the order was reversed. Other slight changes were also made in the decoration of the case. The pillars and top were often elaborately carved. Three of these clocks are illustrated in Figs. 246 to 248. All three are one-day clocks and have wooden works. The first is by Seth Thomas and is the property of The Frederick W. Hoffman Co., 79–83 North Pearl Street, Albany, N. Y.; the second is by Rodney Brace, North Bridgewater, Mass., and is in Essex Institute, Salem, Mass.; the third belongs to George Abree, of Concord, Mass.

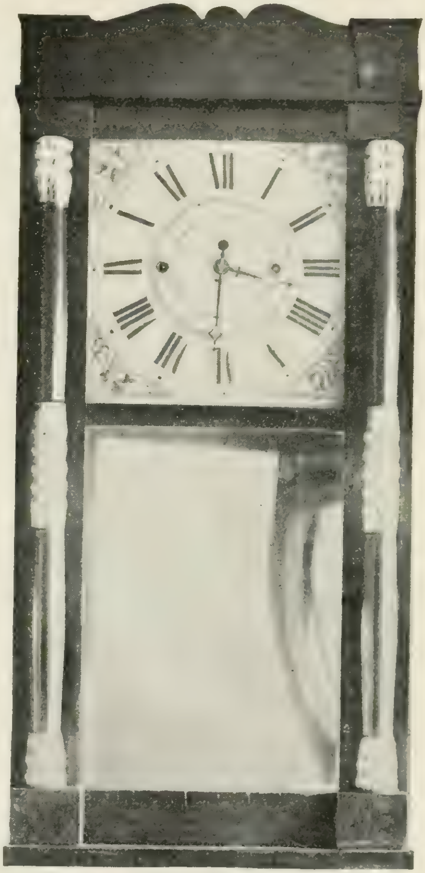


FIG. 248. — A BRONZE LOOKING-GLASS CLOCK.

In 1837 came the great panic and a general breakdown of business including that of clockmaking. Also in this same year occurred the second great invention by Jerome. The events leading up to it and the circumstances attending it can be best stated by piecing together extracts from Jerome's own book. In various places he says: "Wood

clocks were good for time, but it was a slow job to properly make them, and difficult to procure wood just right for wheels and plates, and it took a whole year to season it. No factory had made more than ten thousand in a year; and they were always classed with wooden nutmegs and wooden cucumber seeds. . . . Here then we had the eight-day brass clock costing about twenty dollars; the idea had always been that a brass clock must be an eight-day and all one-day should be of wood, and the plan of a brass one-day had never been thought of. . . . At Richmond I was looking after our old accounts,[1] settling up, collecting notes, and picking up some scattered clocks. One night I took one of these clocks into my room and placing it on the table, left a light burning near it, and went to bed. While thinking over my business troubles and disappointments, I could not help feeling very much depressed. . . . That minute I was looking at the wood clock on the table and it came into my mind instantly that there could be a cheap one-day brass clock that would take the place of the wood clock. I at once began to figure on it; the case would cost no more, the dial, glass, and weights and other fixtures would be the same, and the size could be reduced. I lay awake nearly all night thinking this new thing over. I knew there was a fortune in it." To make this long story short, the one-day brass clock was invented by Jerome in 1837 and just as the Terry patent shelf clock drove out the grandfather clocks and the wag-on-the-walls, and just as the bronze looking-glass clock had driven out the Terry clocks, so this newly invented one-day brass clock drove out all wood clocks. From this year on clockmaking at Bristol was again flourishing. In the single year 1841 Jerome made twenty-five thousand dollars clear profits.

In 1842 Jerome sent a consignment of brass clocks to England. This was perhaps the first considerable number of clocks ever sent to Europe for sale. It took some time and trouble to introduce them and build up a market, but he finally succeeded and then others quickly followed his

[1] This was in the year 1837.

example. He relates one interesting episode in his book: "The Revenue laws of England are (or were at that time) that the owner of property passing through the custom-house shall put such a price on his goods as he pleases, knowing that the government officers have a right to take the property by adding ten per cent to the invoiced price. I had always told my young men over there to put a fair price on the clocks, which they did; but the officers thought they put them altogether too low, so they made up their minds that they would take a lot, and seized one ship-load, thinking we would put the prices of the next cargo at higher rates. They paid us the cash for this cargo, which made a good sale for us. A few days later, another invoice arrived which our folks entered at the same prices as before; but they were again taken by the officers paying us cash and ten per cent in addition, which was very satisfactory to us. On the arrival of the third lot, they began to think they had better let the Yankees sell their own goods and passed them."

Wood in his *Curiosities of Clocks and Watches*, which was published in London in 1866, has this to say about American clocks: "American clocks have found great favour with the public, and by reason of their portability and the neatness of their exterior, have much superseded the old familiar Dutch clocks. They are of inferior workmanship, and lack altogether that finish for which the English workman is justly proud."

In 1844 Chauncey Jerome moved to New Haven. His factory there was only for making the cases and boxing the finished clocks. The movements were still made in Bristol. In 1845 fire destroyed one of the Bristol factories and after that both movement and case were made in New Haven. Jerome's business continued a large one and his product was so good that many small manufacturers used Jerome labels for their poorer clocks. Several law-suits grew out of this practice. In 1850 a joint stock company was formed in New Haven under the name of the Jerome Manufacturing Co. This was the beginning of the downfall of Chauncey

Jerome, who believed too implicitly in the honesty of all men. In 1855 the company failed and Jerome was bankrupt. The last years of his life he spent almost in obscurity and died in very straitened circumstances.

The New Haven Clock Co. succeeded the Jerome Manufacturing Co., and Hiram Camp was its first president. This position he held for forty years. Hiram Camp, whose picture is given in Fig. 249, was born in Plymouth, Conn., April 9, 1811. He was the son of Samuel Camp, Jr., and Jeanette Jerome, sister of Chauncey Jerome. At the age of eighteen he left home and went to Bristol to work at clock manufacturing with his uncle. In 1845 he removed to New Haven, where he died July 8, 1893.

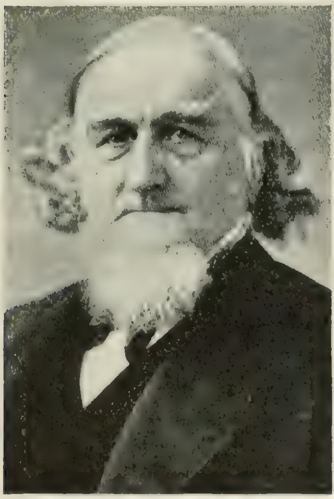


FIG. 249. — HIRAM CAMP (1811–1893).

From what has been written in the preceding pages it might be supposed that there were practically only three clockmakers in Connecticut between 1800 and 1860, namely, Eli Terry, Seth Thomas, and Chauncey Jerome. This is not the case, however. As in all lines of business so also in clockmaking, as soon as it was successful, clockmakers sprang up like mushrooms in the night all over Connecticut and in fact the whole country. There were many of them, some making but a few clocks and others doing a fairly large business. One writer states that in 1850 there were 1436 clockmakers in the country. Terry, Thomas, and Jerome had the inventive genius and the business enterprise. They invented and led; others imitated and followed after. It would of course be impossible, and indeed wearisome, to give in barest outline the life history and achievements of even the more important of them. For such de-

tails the reader must be referred to lists of American clockmakers (see Appendix V). Unfortunately, there is no list which is complete or contains much biographical material. In fact but little is known about most of the clockmakers. The clockmaking industry was centered in Connecticut and this one state between 1800 and 1860 did more than all the other states put together. In Connecticut clockmaking was confined chiefly to the three counties of Litchfield, Hartford, and New Haven. The great centers in these counties were Plymouth (including Thomaston and Terryville), Bristol, Waterbury, Winsted, and New Haven. Chauncey Jerome enumerated what he considered in 1860 to be the five most important clock companies in Connecticut. They were The New Haven Clock Co. of New Haven (who were the direct followers of the Jerome Manufacturing Co. when it failed), the Waterbury Clock Co. of Waterbury (who were successors to the Benedict and Burnham Co.), the Seth Thomas Co. of Plymouth Hollow (now Thomaston), William L. Gilbert of Winsted, and E. N. Welch of Bristol. He remarks about them that in 1860 the New Haven Company was making about 200,000 clocks a year and the remaining four about 300,000.

It must also not be supposed that shelf clocks are all very nearly alike. To be sure there are only six varieties: (1) those made before 1814, of which there are practically none in existence, (2) Terry's patented wood clock of 1814, (3) the later form of Terry's patented clock, (4) Jerome's bronze looking-glass clock, invented in 1825, (5) Jerome's one-day brass clock, invented in 1837, and (6) the eight-day brass clock, which was made in small numbers during the whole period. The shelf clocks, made by different clockmakers, differ quite a little. Five shelf clocks with brass works are pictured in Figs. 250 to 254. These illustrate types five and six. Types two, three, and four have already been illustrated.

The first (Fig. 250) is from a photograph furnished by Miss Mary H. Northend, of Salem. The next two are in Essex Institute, Salem, Mass. The first one (Fig. 251) is

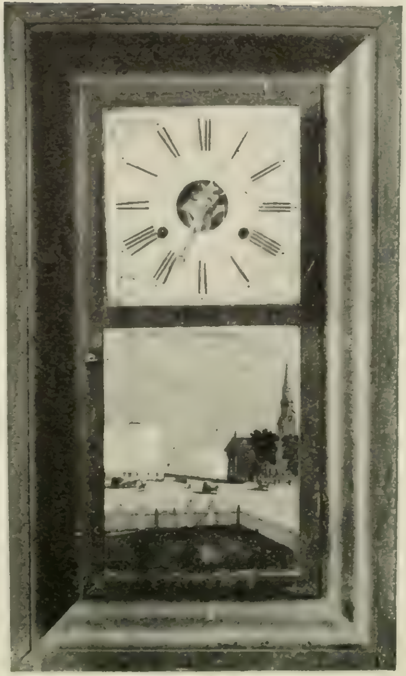


FIG. 251. — A SHELF CLOCK, BY WILLIAM S. JOHNSON.

FIG. 250. — A SHELF CLOCK WITH BRASS MOVEMENT.

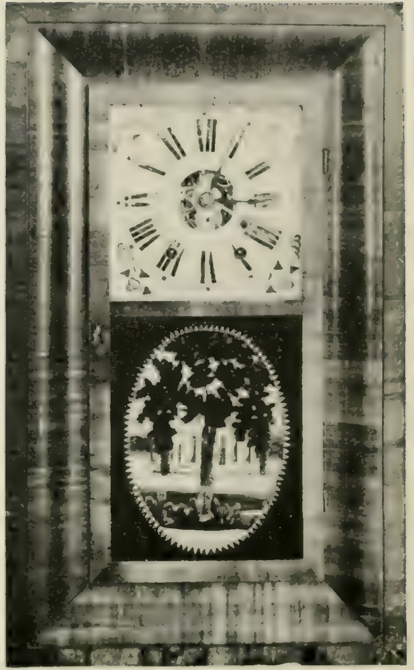


FIG. 252. — A SHELF CLOCK, BY E. C. BREWSTER & CO., OF BRISTOL.

FIG. 253. — AN EIGHT-DAY SHELF CLOCK, BY WILLIAM S. JOHNSON, 16 CORTLANDT STREET, NEW YORK.

FIG. 254. — A SHELF CLOCK, BY CHAUNCEY JEROME.

FIG. 255. — A SMALL SHELF CLOCK.

by William S. Johnson of New York, with a picture of Barnum's Museum and St. Paul's Church. The second (Fig. 252) is by E. C. Brewster & Co. of Bristol. The next two are owned by the author. The first one (Fig. 253) is an eight-day clock with brass movement, by William S. Johnson, 16 Cortlandt Street, New York, and is absolutely original throughout. The date is about 1830. The second (Fig. 254) is also original in every way and was made by Chauncey Jerome himself at Bristol. It has a one-day brass movement.

FIG. 256. — A STEEPLE CLOCK.

After 1850 or at any rate 1860, many varieties of clocks began to be invented. In fact it is the beginning of the modern tendency towards an enormous variety in the output. There are two kinds of clocks, however, which came into vogue shortly after 1850 and are usually classed among "antiques" and not among the endless varieties of modern clocks. These are the small, spring-driven, brass shelf clock often in a rosewood veneer case and the steeple clock, sometimes called the "Sharp Gothic." An example of the first kind is pictured in Fig. 255. It was made by E. N. Welch of Bristol, whom Jerome in 1860 considered to be one of the five largest manufacturers of clocks in Connecticut. The case is quite simple and about eighteen inches high and twelve inches wide. It is a rosewood veneered case, the door containing a piece of plain glass to cover the dial and below that a painted glass panel. This picture is original, but it began to chip off and has been "fixed." It has a one-day brass movement with pendulum. It is spring-

driven and a striking clock, using the usual count wheel. A steeple clock is pictured in Fig. 256. This was made by William L. Gilbert of Winsted, whom Jerome in 1860 also considered to be among the first five clockmakers in Connecticut. It is twenty inches high and ten inches wide. The peak or gable rises between two pillars which are surmounted by pinnacles. The movement is the same as that just described. The case is mahogany veneer. The painted picture was broken and the present one is not the original. The pinnacles are "mahogany finish." This kind of clock is said to have been designed by Elias Ingraham, who was the founder of the present firm of E. Ingraham Co. of Bristol, Conn. Elias Ingraham was born in Marlborough, Mass., in 1805 and died in Bristol in 1885. He was by trade a cabinet-maker, and as soon as he came to Bristol, where clockmaking was in the air, so to speak, he immediately turned his attention to the designing of clock cases. It is said that he designed this clock case to while away the tedium of a voyage to South America, whither he had gone to introduce his clocks. In Fig. 257 is illustrated a

FIG. 257. — A STEEPLE CLOCK WITH BASE.

steeple clock with a base. This seems to have been designed at the same time or a little earlier than the usual steeple clock. The clock illustrated is in Essex Institute, Salem, Mass., and was made by Elisha Manross, of Bristol, Conn.

Shelf clocks as antiques. — During the last few years the shelf clock has been much sought after by collectors as an antique. It is perhaps putting it too strongly to say that there is a veritable craze for them, but at any rate, they are in good demand. There is hardly an antique shop anywhere which will not have from one to a dozen of them for sale. The supply is decidedly limited and the demand if anything, is growing stronger. They will be found to be in all conditions. Some are veritable wrecks of time, others have been "renovated," and others have always been kept and still are in good condition.

If a clock has had very bad treatment and nothing has been done to make good the damage, it may be found that the case has had several coats of varnish, jap-a-lac, or even paint, that the veneer is broken off in places, that the painted panel has been broken, that the case is warped, that the movement is very dirty, that one or both of the weights are missing, that the pendulum spring is broken, that the hands are missing, and that the movement in general needs overhauling. These are the more usual defects and more than half of the clocks are picked up in this condition. More will be said about repairing such clocks in a later chapter.

When a clock has been "renovated" in an antique shop, the process has often gone too far. Too much new material has been put into the case and movement and sometimes parts of two or three clocks are used to make one good one. A clock which has always had good treatment and is in fine condition is not often met with.

About nine out of ten of these shelf clocks will still have the clock paper. Since these so-called clock papers play such a large part in determining the maker and thus age of a clock, more will be said about them. A little after 1800 clockmakers got the idea of putting a printed paper inside

the case of each clock. This paper usually contained the name of the maker and his place of business, directions for setting the clock going, directions for regulating the clock, and the like. They thus had a double use. They advertised the maker and at the same time gave useful information to the owner. These papers were never put in grandfather clocks but nearly all shelf clocks have them. The fact that in spite of the lapse of time and in spite of renovation about ninety per cent of the shelf clocks still have the original papers speaks well for the adhesive which was used. As an example, the paper in the clock by Chauncey Jerome pictured in Fig. 254, reads as follows:

BRASS CLOCKS,

MADE AND SOLD BY

CHAUNCEY JEROME

BRISTOL, CONN.

Warranted good

Directions for setting the Clock running and keeping in order.

N. B. The clock can be set running without taking off the hands or dial plate. Put the pendulum through the loop at the end of the wire at the bottom of the dial, and hang it in the stud above.

Oil the pallets or ends of the part commonly called the verge, the pin on which the verge plays, and the wire which carries the pendulum at the place where it touches the rod. One drop of oil is sufficient for the whole.

Care should be taken not to wind the clock until the cord is put upon the pulley in the partition and also on top of the case and the weights put on. The light weight on the strike side of the Clock.

To wind up the weights put in the key with the handle down, turn towards the figure six, and turn steady until the weight is up.

If the hands want moving, do it by means of the longest, turning it at any time forward, but never backward when the Clock is within fifteen minutes of striking; and in no case no farther than to carry the minute hand up to figure XII.

Directions for regulating the Clock.

This is done by means of a screw at the bottom of the pendulum. If the clock should go too fast lower the ball, if too slow, raise it.

ELIHU GEER, *Job, Card, and Fancy Printer*, Hartford, Conn.

The question is often asked as to the present value of these shelf clocks. It cannot be definitely answered, since they are nearly always purchased at antique shops, and the antique business is notorious. Shelf clocks made prior to 1814 are not in the market. There are extremely few of them and they are never offered for sale. A Terry patent wood clock in first class condition, with clock paper, and the original painted glass panel is worth about $50. If made by Eli Terry himself or by Seth Thomas it would be worth perhaps thirty per cent more; without a clock paper it would be worth about twenty per cent less; and without the original painted glass panel about thirty per cent less. A renovated clock has about two thirds of the value of one which has always been kept in good condition. A "wreck" has about one fifth the value; the price of course here depends a good deal upon its condition. A shelf clock like Jerome's bronze looking-glass clock with clock paper and original panel and in first class condition is worth about $25. A one-day shelf clock with brass works is worth about $15. An eight-day shelf clock with brass works is worth about $20. A small spring-driven one-day shelf clock is worth about $10. A steeple clock is worth about $12. These values are subject to the same discounts as before for loss of clock paper, broken panel, and poor condition. These prices are, naturally, intended for the average clock of each kind. A particularly ornate and beautiful example would of course bring more; a very plain one would be much less valuable. Walter A. Dyer, in his article, "Some Old Clocks," in *Country Life in America*, July, 1907, has this to say about the value of Connecticut shelf clocks: "Terry clocks are worth very nearly what they were when new — $15 to $40 for the different kinds. Cheap Connecticut wall

and shelf clocks of the nineteenth century are also worth from \$15 to \$40."

Massachusetts clockmakers — the banjo clock. — In the manufacture of clocks between 1800 and 1860 Massachusetts stood next to Connecticut. The most famous clockmakers in Massachusetts were without doubt the Willards — famous not only because they made excellent clocks of many different kinds but also because they originated a new kind which has been a popular favorite, namely, the banjo clock.

Simon Willard, the progenitor of the Willard family in America, was the founder of Concord, Mass. Benjamin Willard, son of Joseph, son of Benjamin, son of Simon, the pioneer settler, was born in Framingham, Mass., in 1716. He had a family of twelve children, four of whom, Benjamin, Jr., Simon, Ephraim, and Aaron, became clockmakers. Two of these, Benjamin, Jr., and Ephraim, are but little known. The two famous Willard clockmakers are Simon and Aaron.

Benjamin Willard, Jr., was born in Grafton, March 19, 1743. His clocks are marked Grafton, Lexington, or Roxbury, thus showing the various places at which he carried on business. It is not known where he carried on his business in Grafton or from whom he learned the clockmaker's trade. He probably left Grafton for Lexington between 1766 and 1771. In 1771 he removed to Roxbury, and in 1783 he reappears in Grafton. Some time in 1801 he went to Boston and in 1803 he went to Baltimore, Md., where he died the same year. He probably made only grandfather clocks.

Simon Willard, the most famous of the family, was born in Grafton, April 3, 1753. He had a limited schooling which, however, included the study of Latin. It is stated by a couple of writers that he was apprenticed at the age of twelve to a Mr. Morris, an Englishman. Nothing, however, is known about him. He found himself in his natural element, and inside of a year was making a clock superior to those of his teacher. He remained in Grafton, making

clocks until about 1780. He then removed to Roxbury and set up his shop at what is now 2196 Washington Street. Here he remained until his retirement in 1839, nearly sixty years later. Simon Willard married his cousin, Hannah Willard, November 29, 1776, but she died less than a year later. On January 23, 1788, he married Mrs. Mary (Bird) Leeds, widow of Richard Leeds, and they had eleven children. In 1839 he retired from active business and from then on lived with first one, then another of his children. He died August 30, 1848, aged 95 years. His picture when 92 years of age is shown in Fig. 258.

FIG. 258. — SIMON WILLARD WHEN NINETY-TWO YEARS OF AGE.

In 1801 Simon Willard invented what he called an "improved timepiece" and applied for a patent. It was granted February 8, 1802. This improved timepiece was nothing more or less than the banjo clock, as it is now always called, although that term was never used by the Willards. It was an instant and complete success and became at once a popular favorite. Undue stress is laid by some upon the words "improved timepiece." They would infer from the word "improved" that the banjo clock was already being made, and perhaps had been invented by some one else, namely, Aaron Willard. It is also inferred that this early banjo clock did not strike the hours, as it is called a *timepiece*. And this seems to be true, for all of the early banjo clocks are not striking clocks.

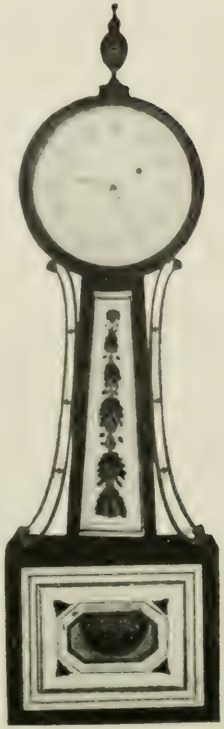
The cases of the early banjo clocks were usually quite plain and sensible. They consisted of mahogany, gilded wood, painted glass, and sometimes brass ornaments. Gilded wood was always used in moderation. The top or-

nament consisted of a brass or wood acorn, or a ball. The brass spread eagle is said to indicate "restoration." It is a debatable question if the gilded wood spread eagle should be placed in the same category. Some Simon Willard banjo clocks which show no traces of 'restoration' have a gilded wood eagle. There was usually no base piece, although it is found on some fine presentation clocks. The highly gilded and decorated banjo clocks often seen at present have either been "renovated" or are by later makers. The movement is always an eight-day movement made of brass, weight-driven, and provided with a pendulum whose time of swing is between a second and a half second.

Three Simon Willard banjo clocks in their original condition are pictured in Figs. 259 to 261. These illustrations are taken from the very excellent and interesting book, *A History of Simon Willard, Inventor and Clockmaker*, by John Ware Willard. The first clock is owned by the author, John Ware Willard, the second by Miss Theodora Willard of Cambridge, Mass., and the third by Francis H. Bigelow, of Cambridge, Mass. It is estimated that Simon Willard made about 4000 timepieces.

About Ephraim Willard but little is known. He was born in Grafton, March 18, 1755, and remained there until 1776. In 1777 he appears in Medford as a clock and watchmaker. In 1798 he was residing in Medford and in 1801 he removed to Boston. Later he went to New York and presumably died there. There are very few clocks made by him and they are all grandfather clocks.

Aaron Willard, the other famous clockmaker, was born in Grafton October 13, 1757. Nothing is known about his early life in Grafton or from whom he learned clockmaking. In 1780 he removed to Roxbury and was located at what is now 2224 Washington Street. Between 1792 and 1798 he established his factory in Boston. The Boston Directory for 1798 contains "Aaron Willard, Clock-maker, on the Neck." He did a large business and sometimes employed twenty or thirty workmen. He retired from business in 1823 and died in 1844. He was twice married and had



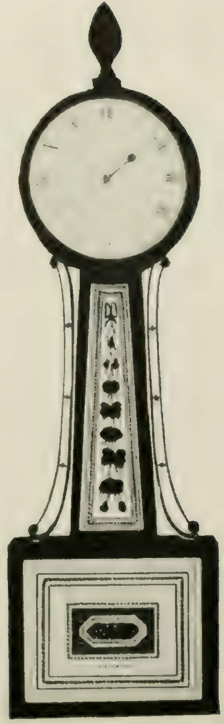


FIG. 259. — A SIMON WILLARD BANJO CLOCK. FIG. 260. — A SIMON WILLARD BANJO CLOCK. FIG. 261. — A SIMON WILLARD BANJO CLOCK.

FIG. 262. — A BANJO CLOCK, BY AARON WILLARD.

FIG. 263. — A BANJO CLOCK, BY AARON WILLARD.

FIG. 264. — A BANJO CLOCK, BY AARON WILLARD.

FIG. 265. — A GRANDFATHER CLOCK, BY SIMON WILLARD.

FIG. 266. — A GRANDFATHER CLOCK, BY SIMON WILLARD.

FIG. 267. — A GRANDFATHER CLOCK, BY AARON WILLARD.

nine children. The banjo clocks made by Aaron Willard were usually more ornate than those made by his brother Simon. Simon Willard, for example, never used a naval battle, American flag, or a landscape on the glass fronts. These designs were peculiar to Aaron Willard or other makers. Three banjo clocks by Aaron Willard are illustrated in Figs. 262 to 264. The first two are in Essex Institute, Salem, Mass., and the third belongs to Mrs. William Page Andrews, Williamstown, Mass.

Simon and Aaron Willard made many other kinds of clocks besides the banjo. In fact the making of banjo clocks was but a small part of their business. They made town clocks, accurate clocks to serve as regulators and for astronomical purposes, grandfather clocks, and in short, all kinds of domestic clocks. A handsome volume entitled *A History of Simon Willard, Inventor and Clockmaker*, by John Ware Willard, published in Boston in 1911, gives much information about the Willard family and contains some fine pictures of the clocks. Two grandfather clocks made by Simon Willard are pictured in Figs. 265 and 266. The first was originally owned by General Pierce, father of President Franklin Pierce and is now owned by Mrs. Charles Stark, at Dunn Barton, N. H. The second is owned by

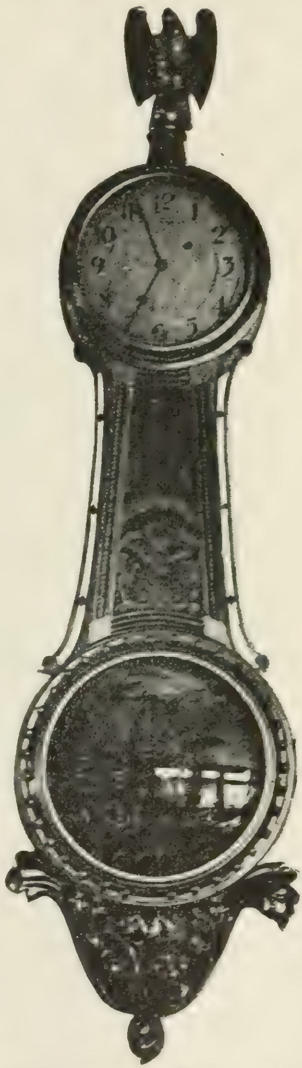


FIG. 268. — A CURTIS BANJO CLOCK AT THE RED LION INN, AT STOCKBRIDGE, MASS.

Richard Harrington. A grandfather clock made by Aaron Willard and owned by the author is shown in Fig. 267.

A second Massachusetts clockmaker to gain fame through the banjo clock was Lemuel Curtis. He was born in Boston in 1790 and moved to Concord in 1814, where he started a clockmaking establishment. In 1816 he patented an improvement on the Willard banjo clock. In 1818 or 1820 he

FIG. 269. — A BANJO CLOCK, BY AN UNKNOWN MAKER.

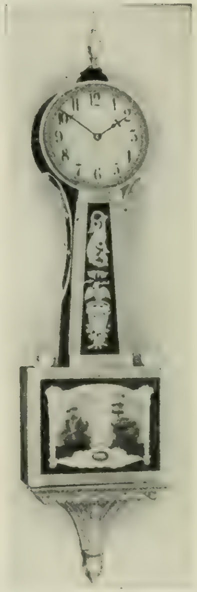


FIG. 270. — A MODERN BANJO CLOCK, BY THE WALTHAM CLOCK CO.

moved to Burlington, Vt., where he died in 1857. There are a number of his banjo clocks in existence and they are almost without exception handsome clocks. In Figs. 268 to 270 three banjo clocks are illustrated. The first is by Curtis and is at the Red Lion Inn, at Stockbridge, Mass. The second is by an unknown maker. The third is a modern banjo clock as made by the Waltham Clock Co.

Banjo clocks are valuable. A fine one by Willard or Curtis in first class condition is worth perhaps \$150 to \$250.

Modern copies of these sell for about $75. Walter A. Dyer, in an article, "Some Old Clocks," in *Country Life in America*, July, 1907, has this to say about the value of Willard clocks:

FIG. 271. — A LYRE CLOCK.

"Willard tall clocks are worth $250 to $300, if in good condition; other American tall clocks vary in value from $150 to $350, because the materials and workmanship in

the cases vary so widely. Willard banjo clocks are worth from $35 to $175, according to workmanship and beauty."

In Figs. 271 and 272 are shown two other varieties of clocks. These may be called the "Lyre" clock and the "Acorn" clock. They are both very uncommon and made always by Massachusetts makers. The Lyre clock is by Sawin & Dyer, Boston, and is in the Metropolitan Museum of Art in New York City. The Acorn clock is at the Red Lion Inn in Stockbridge, Mass.

FIG. 272. — AN ACORN CLOCK.

The shelf clock of the Connecticut type was also made in large numbers in Massachusetts. There also developed another form which is radically different and may be called the "Massachusetts shelf clock." In fact this form of shelf clock may have been made in Massachusetts even before Terry began his experiments with shelf clocks. Terry's patented shelf clock dates, it will be remembered, from 1814. The Willards and others were probably making the Massachusetts shelf clock as early as 1790. Three of these shelf clocks are illustrated in Figs. 273 to 275. The first is by Simon Willard and owned in Salem, Mass., the second is by S. Crane and is in the Museum of Fine Arts at Boston; the third is by David Wood, of Newburyport, Mass.

In size these clocks are about the same as Jerome's bronze looking-glass clock. The movement was always of brass. It will be noticed that they are much alike but that they are radically different from the Connecticut shelf clock.

Modern clock companies. — The following list contains most of the largest and best known of the present day clock

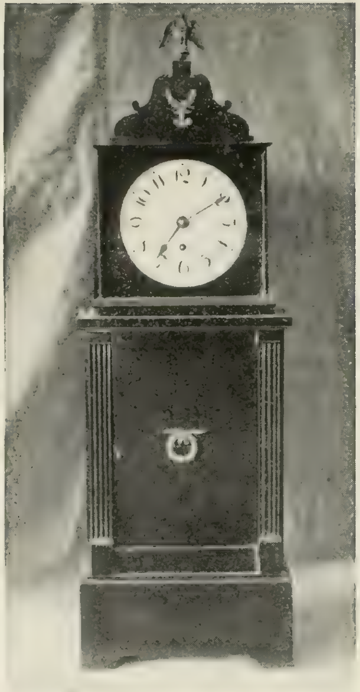


FIG. 273. — A MASSACHUSETTS SHELF CLOCK, BY SIMON WILLARD.

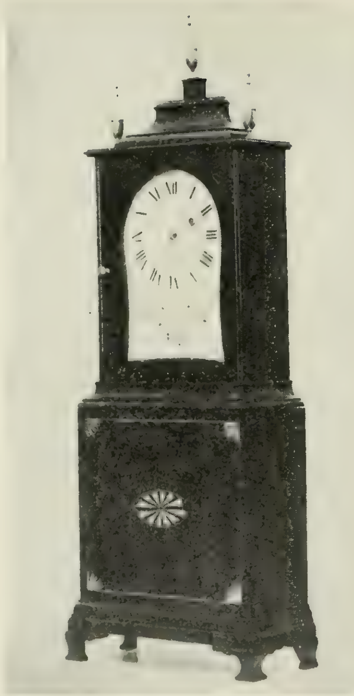


FIG. 274. — A MASSACHUSETTS SHELF CLOCK, BY S. CRANE.

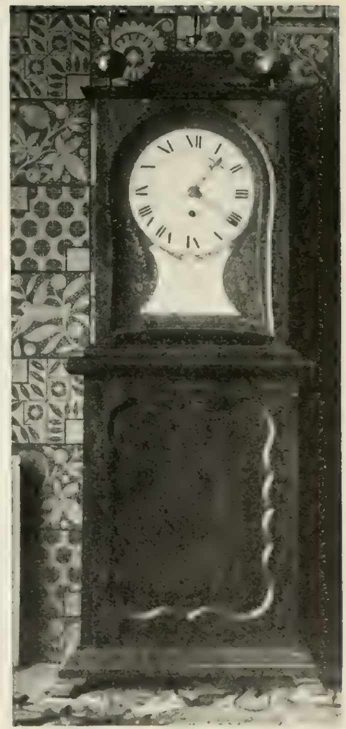


FIG. 275. . — A MASSACHUSETTS SHELF CLOCK, BY DAVID WOOD.

manufacturing companies. It was obtained by asking about a half dozen jewelers to name as many present day clock manufacturing companies as they could without looking them up. The result of these inquiries was the following list (in alphabetical order) of the companies:

Chelsea Clock Co., Boston, Mass.
W. L. Gilbert Clock Co., Winsted, Conn.
E. Howard Clock Co., 373 Washington St., Boston, Mass.

FIG. 276. — THE ORIGINAL SHOP IN WHICH SETH THOMAS FIRST STARTED WORK. (Seth Thomas Clock Co.)

E. Ingraham Co., Bristol, Conn.
New Haven Clock Co., New Haven, Conn.
Sessions Clock Co., Forestville, Conn.
Seth Thomas Clock Co., Thomaston, Conn.
Waltham Clock Co., Waltham, Mass.
Waterbury Clock Co., Waterbury, Conn.
Western Clock Co., La Salle, Ill.

It will be noticed that six of these ten companies are Connecticut companies and that three belong to Massa-

chusetts. At least five of the six Connecticut companies date back to the early days of clockmaking before 1860.

The Seth Thomas Clock Co., of Thomaston, Conn., is one of the oldest and largest of these companies. The business was carried on by Seth Thomas himself from 1813 to 1853 when it was incorporated as the Seth Thomas Clock Co. A picture of the original shop in which Seth Thomas first started work is shown in Fig. 276. The manu-

FIG. 277.—THE MOVEMENT SHOP OF THE SETH THOMAS CLOCK CO.

facturing of the wooden wheel movements stopped in 1837. Between 1813 and 1853 the product consisted primarily of shelf clocks with a few small mantel clocks and regulators. The regulators were first made in the early forties. The first perpetual calendar clocks were made in 1860; the first lever movement in 1865; the first tower clocks in 1872. The first one-day back-wind alarm clock in a round metal case was made in 1876. (This is supposed to be the first production of such a clock in this country.) Watches were made from 1884 to 1914, when their manufacture was discontinued.

The first chimes were made in 1884. Secondary and master clocks and electric clock systems were first made in 1910. At the present time the Seth Thomas Clock Co. manufactures practically every variety of clock, including marine clocks, electric clocks, and tower clocks. The plant consists of a main building, movement shop, case shop, marine shop, etc. A picture of the movement shop, showing the pleasant location, is reproduced as Fig. 277.

A few rambling comments concerning some of the other companies and their output may be of interest. Tower clocks are made chiefly by the Seth Thomas Clock Co. and the E. Howard Clock Co. Banjo clocks are made by nearly all of the companies. The Western Clock Co. is best known as the maker of "Big Ben" and all the other Bens. The Waltham Clock Co. specializes in modern grandfather clocks and regulators. The Waterbury Clock Co. has always made many watches for R. H. Ingersoll & Bro. In fact it was one of the three places where the Ingersoll watch was made. Very recently (winter, 1922), due to the failure of R. H. Ingersoll & Bro., the Waterbury Clock Co. has purchased the Ingersoll interests.

Statistics on clockmaking in the United States. — Lest this chapter prove to be too interesting, it will close with some statistics on clockmaking. It is said that there is nothing so deadly dry and fatal to interest as tables of statistics. The following are, however, the interesting kind. The statistics have been obtained from *The Statistical Abstract of the United States* which is published annually by the Department of Commerce and from Vol. VIII (Manufacturers) of the *Thirteenth Census of the United States* (1910).

Table I contains figures as regards the number of establishments, value of products, and the like in connection with clocks and watches, including cases and material. It is interesting to note that while the capital has doubled in the fifteen years between 1899 and 1914 and wages and value of products have increased about 50 per cent, the number of establishments has remained just about the same.

Table II gives the figures for clocks, watches, etc., sepa-

rately for the single year 1909. It is safe to assume that similar ratios would hold for the other years. It will be seen that as regards value of products clocks represent about one third, watches about one third, and watch cases about one third, and that the other item is negligible.

Table III contains comparative figures for clocks for different years. The output has been multiplied by twenty and the number of companies not much more than doubled.

Table IV contains figures as regards imports, exports, and the export of clocks which have been imported. It will be seen that imports are very small and exports amount to roughly one tenth of the product. About nine tenths of American made clocks are thus sold at home.

Table V contains statistics as to the size of the various firms. It will be seen that there is a decided tendency towards large companies.

Table VI gives figures as to the age and sex of the wage earners employed. Roughly twice as many men as women are employed.

Table VII gives statistics for the single year 1909 for the United States as a whole and for various states. As regards value of products Connecticut leads with 21 per cent, Illinois comes second with 20 per cent, and New York third with 17.6 per cent.

Table VIII, which gives the figures for clockmaking alone, brings out still more markedly the supremacy of Connecticut. This concentration of industry is, however, lessening with time.

TABLE I

Clocks and Watches, Including Cases and Materials

Census Year	Number of Establishments	Salaried Employees	Wage Earners	Capital	Salaries	Wages	Cost of Materials	Value of Products
1899	109	676	17,155	$31,514,000	$957,000	$8,315,000	$8,819,000	$22,110,000
1904	97	1249	22,579	42,189,000	1,638,000	11,892,000	9,872,000	29,790,000
1909	120	1529	23,857	57,500,000	2,181,000	12,944,000	11,131,000	35,197,000
1914	119	1690	23,328	62,469,000	2,303,000	13,495,000	11,021,000	34,153,000

TABLE II

DETAILED STATISTICS FOR THE YEAR 1909

	NUMBER OF ESTABLISHMENTS	WAGE EARNERS	WAGES	COST OF MATERIALS	VALUE OF PRODUCTS
Clocks	52	7,961	$4,142,344	$3,692,754	$12,235,631
Watches	13	10,684	6,085,700	2,185,825	11,771,065
Watch cases	29	4,569	2,428,262	5,034,377	10,514,854
Watch and clock materials	26	643	287,863	217,742	675,292
Total	120	23,857	$12,944,169	$11,130,698	$35,196,842

TABLE III

CLOCKS

	NUMBER OF ESTABLISHMENTS	WAGE EARNERS	WAGES	COST OF MATERIALS	VALUE OF PRODUCTS
1919	46	8,252	$7,861,611	$7,177,813	$23,380,190
1914	48	6,754	3,653,146	4,007,764	11,031,720
1909	52	7,961	4,142,344	3,692,754	12,235,631
1904	38	7,249	3,514,185	3,077,574	8,868,000
1899	46	6,037	2,650,703	3,028,606	7,157,856
1889	27	3,491	1,808,025	1,457,778	4,228,846
1879	22	3,940	1,622,693	1,908,411	4,110,267
1869	26	1,330	805,340	818,409	2,509,643
1859	22	975	391,320	474,668	1,187,550
1849	23	800	278,508	456,834	1,181,500

TABLE IV

CLOCKS AND PARTS	1905	1906	1907	1908	1909	1910
Imported	$486,765	$539,793	$610,060	$471,133	$468,597	$701,852
Exported	1,192,246	1,304,451	1,440,290	1,461,989	1,265,795	1,360,218

CLOCKS AND PARTS	1911	1912	1913	1914	1915	1916
Imported	$869,282	$681,972	$809,715	$905,421	$705,555	$234,796
Exported	1,565,901	1,661,468	1,823,008	1,552,725	1,660,033	2,593,826
Exported imports	2,440	1,822	3,030	4,251	880	1,076

TABLE IV—*Continued*

Clocks and Parts	1917	1918	1919[1]	1920	1921
Imported	$70,929	$106,525	$141,754	$601,678	$1,056,660
Exported	2,532,266	2,110,022	3,920,514	4,897,972	2,492,533

[1] Calendar year, not to June 30 as previously in the figures 1905 to 1918, inclusive.

TABLE V

Clocks and Watches, Including Cases and Materials

1909	Value of Product				
Number of establishments Total	Under $5,000	$5,000 to $20,000	$20,000 to $100,000	$100,000 to $1,000,000	Over $1,000,000
120	25	22	31	34	8

TABLE VI

	1909
Wage earners	23,857
Males over 16	14,716
Females over 16	8,640
Under 16	501

TABLE VII

Clocks and Watches, 1909, Including Cases and Materials

	Establishments	Wage Earners	Capital	Wages	Value Of Products
United States	120	23,857	$57,500,000	$12,944,000	$35,197,000
Connecticut	16	5,851	9,846,000	3,030,000	7,390,000
Illinois	19	5,665	12,412,000	3,217,000	7,045,000
New Jersey	9	2,129	6,795,000	1,120,000	3,848,000
New York	27	2,467	8,044,000	1,385,000	6,184,000
Ohio	9	1,456	4,232,000	784,000	1,981,000
Pennsylvania	8	1,395	4,651,000	728,000	2,873,000
All others	32	4,894	11,520,000	2,680,000	5,876,000

TABLE VIII

Clocks (Value of Products)

Year	United States	Connecticut	
1904	$8,868,000	$6,158,034	69.4%
1909	12,235,631	6,809,746	55.7%

CHAPTER XXI

THE HISTORY OF WATCHMAKING IN AMERICA

There are two distinct periods in the history of watchmaking in America. The first extends from the earliest colonial days until 1850. This was the era of individual effort. But few watches were made and only hand tools were used. The second period is the interesting one and extends from 1850 to the present time. It is remarkable for the inception and development of the great watch factories of to-day.

The first period, which extended from the earliest colonial days until 1850, contains but little of interest. The first watchmakers, like the first clockmakers, came from England and Holland. They had learned their trade before they came, they brought their tools with them, and they made the kind of watches which they had been making before they came. Later many learned their trade in this country and some came from Switzerland. Only hand tools were used, and usually one man made all the parts of a watch. A large portion of the supplies, such as hands, springs, jewels, and the like, was often imported from Europe. A watchmaker generally imported, repaired, and sold watches as well as made them and clocks were nearly always included in the business as well. The number made by each watchmaker was necessarily small. Sometimes a more prosperous one might employ two or three men and have a couple of apprentices.

Between 1800 and 1850 there were a few instances when a larger number of watches were made and it could almost be said there was a watch factory. Luther Goddard of Shrewsbury, Mass., was in the watchmaking business on a large scale from 1809 to 1817 when he retired. He made perhaps 500 movements, the largest number by far ever

made by any one manufacturer up to that time. From 1838 to 1841 James and Henry Pitkin were making watches first at Hartford, Conn., and later in New York City. They made perhaps 800 movements and used the most elaborate tools which had ever been used for watchmaking. Power may have been used for driving some of them. Perhaps these should be considered the first watch factories, but nothing came of their efforts.

The second period, which extends from 1850 to the present time, is remarkable for the rise, development, and marvelous growth of the watchmaking business. In fact it is the most marvelous growth that the world has ever seen in connection with any mechanical business. The first clock factory was established at Plymouth, Conn., shortly after 1800, and from this small beginning the giant clock industry of the present day has developed.

In the same way, fifty years later, or a little after 1850, the first watch factory was established at Roxbury, now a part of Boston, Mass., and from this small beginning the giant watch factories of to-day take their origin.

The first watch factories in America. — The two pioneers who brought this about were Aaron L. Dennison and Edward Howard, whose pictures are reproduced in Figs. 278 and 279. A little before 1850 we find these two close friends both enthusiastic over the idea of making watches by factory methods, using automatic machinery, and on the interchangeable plan, that is, with each part of every watch exactly the same. In fact these seem to have been their fundamental principles, namely: (1) factory methods, not individual hand work, (2) automatic machinery, power driven, whenever possible, and (3) absolute interchangeability. On the last principle they seemed particularly insistent. Some claim that these ideas were original with Dennison, and that he fired the enthusiasm of Howard. Others attribute the ideas to Howard and claim that he gained the hearty support of Dennison. Some who support Dennison's claim assent that he often visited the United States Armory at Springfield where muskets were made on

the interchangeable plan. One writer even affirms that he was employed there for a short time. Some claim that Howard wanted to manufacture locomotives rather than watches and that Dennison persuaded him to make it watches. Be this as it may, the fact remains that before 1850 these two close friends were both imbued with the firm belief that watchmaking along these lines would be a success. It is also evident that both men had given, prior to 1850, a good deal of thought to this matter. Dennison in one place writes: "The principal thinking up of the matter was done when I was in business at the corner of Bromfield and Washington Streets in Boston. Many a night after I had done a good day's work at the store, and a good evening's work at home, repairing watches for personal friends, I used to stroll out upon the "Common" and give my mind full play upon this project, and, as far as I can recollect what my plans then were as to system and methods to be employed, they are indentical with those in existence in the principal watch factories at the present time." Howard in one place writes: "One difficulty I found was that watchmaking did not exist in the United States as an industry There were watchmakers so called, at that time, and there are great numbers of the same kind now, but they never made a watch; their business being only to clean and repair. I knew from experience that there was no proper system employed in making watches. The work was all done by hand. . . . As I say, all of these minute parts were laboriously cut and filed out by hand, so that it will be readily understood that in watches purporting to be of the same size and of the same makers, there were no two alike, and there was no interchangeability of parts. Conse-

FIG. 278. - AARON L. DENNISON.

quently, it was 'cut and try.' A great deal of time was wasted and many imperfections resulted. The development of the plan (to use automatic machinery) was the result of long thinking."

It might be well to pause a moment to glance at the early life and training of these two men. Aaron L. Dennison was born in Freeport, Maine, March 6, 1812. His father was a shoemaker and there was a family of eight children, and Aaron was the oldest. His early years were characterized by hard work and little schooling. In 1824 the family moved to Brunswick and his father continued with his old trade of shoemaking. In 1830, when Aaron was eighteen years of age he was apprenticed to James Carey, a watchmaker of the town, with whom he remained three years. In 1833 he went to Boston and entered the employ of Currier and Trot. Later he was with Jones, Low & Ball. Here in Boston he had excellent training in repairing the best hand-made watches of the day. In 1839 he started in business for himself and was soon very successful. He not only repaired watches but carried a full line of materials, tools, and jewelry for sale. It is said that while importing cards, small tags, and boxes for jewelry he conceived the idea that his father might make these more cheaply than they could be imported and that it would at the same time be a more profitable occupation than shoemaking. Accordingly he devised some simple machines and started his father in this business. It proved so successful that the father retired in fifteen years and a son, E. W. Dennison, became the founder of the "Dennison Manufacturing Co." Thus, just before 1850, when the story of the watch factories

FIG. 279. — EDWARD HOWARD.

begins, Dennison was a very successful watchmaker and jeweler of Boston.

Edward Howard was born in Hingham, Mass., October 6, 1813. At an early age he was apprenticed to Aaron Willard, Jr., son of Aaron Willard, one of the famous clockmakers who was mentioned in the history of clockmaking. The Willards were excellent clockmakers, so that Howard received the best of training. Howard was a mechanical genius and made excellent clocks, but he was always enthusiastic over watches and the smaller work. In 1840 Howard went into business for himself and in 1842 he built a small factory at Roxbury for the manufacture of clocks. Thus just before 1850, when the story of the watch factories begins, Howard was a successful manufacturer of clocks at Roxbury, now a part of Boston. His partner in the clock factory was D. P. Davis.

In 1850, as has already been stated, we find these two men, Dennison and Howard, close friends and both eager to start a watch factory. It was first necessary to get funds for the undertaking. This was a hard matter, as it was not a popular enterprise. There was a prejudice against American-made watches. They were told it would never succeed. They were even ridiculed by their friends. Samuel Curtis of Boston was finally persuaded to furnish $20,000 for the enterprise. But little is ordinarily said about Curtis, as he was not a mechanical genius or a watchmaker, but nevertheless his $20,000 probably did fully as much towards the establishing of watchmaking, as the genius and training of Dennison or Howard. Thus all honor to the financial backer, Samuel Curtis! The first money spent in the undertaking was for a tour of observation in the watchmaking districts of England. This was made by Mr. Dennison and he found that the system used in England at the time was that of extreme subdivision of hand labor. That is, each man did one thing, so that a watch would pass through many hands before it was completed. Mr. Dennison also looked up sources of supply for necessary materials.

Work was first started on a model watch and the neces-

sary machines for making it in a small room in Howard's clock factory in Roxbury. These quarters were cramped, however, and a small factory was built across the street from Howard's. This is pictured in Fig. 280. In the summer of 1850 the model of the first watch was completed. It was full plate, 18-size, and designed to run eight days. The mainspring was too long and cumbersome and it was not practicable, so this model was abandoned in favor of a 36-hour one. The firm was known as "The American Horologe Company," and consisted of Dennison, Howard, and Curtis. The machines were built and the first watch put on the market in 1853. In the meantime the name of the company had become "The Warren Manufacturing Co." The first one hundred watches carried the name "Warren" the next six or seven hundred carried the name "Samuel Curtis." These watches were 18-size, full plate, and were sold for $40. The firm name now became "The Boston Watch Co." There were many difficulties to be overcome and much had to be learned by experience. Howard in one place writes: "We did not know how to make a jewel, or a dial, or to do proper gilding, or to produce a mirror polish on steel. We had to study and work over these operations until after many attempts one at last would be successful. We had to invent all the tools to make the different parts. After being designed or invented they had to be made in the factory by our own machinists in order to have them perfect and durable." The factory now proved to be entirely too small. Furthermore, it was very dusty in summer and there were no good locations for the homes of the working men. It was finally decided to move the factory

FIG. 280. — THE FIRST WATCH FACTORY IN AMERICA.

to Waltham, about ten miles west of Boston. The new factory was ready for occupancy in the fall of 1854. The company was now making about five watches per day and employing about ninety hands. The watch movements were engraved "Dennison, Howard, and Davis."

In 1856 things began to go very badly. The constant experimenting took a great deal of time and money. The building of so much automatic machinery was a very expensive matter. The sale of the watches was slow. Perhaps Howard insisted on too high a standard of excellence. In the spring of 1857 the company made an assignment. The property was bid in at the sale by Royal E. Robbins for $56,000 for himself and the firm of Tracy & Baker, watch case makers of Philadelphia. The reorganized firm was known as Tracy, Baker & Co. and Dennison was retained as general superintendent. Howard returned to Roxbury and started again. In one place he comments on this as follows: "I had to begin at the bottom and make all tools anew. I returned to my old factory at Roxbury, and founded a new company with the understanding that I was to have my own way about the quality of watches that bore the name Howard."

From now on the story divides into two parts, for out of Howard's efforts the present E. Howard Watch Works of Waltham was to develop and the reorganized firm of Tracy, Baker & Co. was destined to become the great Waltham Watch Co. of the present time. It might be interesting right here to follow out first the career of Aaron L. Dennison. He retained his position with the newly organized company at Waltham until 1861. In 1864 the Tremont Watch Company was organized. The plan was to have certain parts of the movement made in Switzerland and shipped to the United States. The watches were to be set up and adjusted here. Mr. Dennison was elected superintendent of the company and went to Zürich in Switzerland to oversee the manufacture of parts there. In 1866 the company decided to manufacture the entire movement in this country and Mr. Dennison withdrew. In 1870 he moved to Hans-

worth, a suburb of Birmingham, England. In 1874 he was manufacturing watch cases under a firm name of Dennison, Wigley & Co. He retained his connection with this firm until practically the time of his death on January 9, 1895.

When Howard returned to Roxbury in 1857 he continued the manufacture of clocks in connection with Mr. Davis. But he still had a longing for watchmaking and soon opened up the old factory of the "Boston Watch Co." In 1861 a stock company was organized with a capital of $120,000 known as the "Howard Clock and Watch Company." There were financial difficulties at first, but as time passed the business increased. In 1873 the large factory on the corner of Eustis and Prescott Streets was completed. In 1881, after more financial difficulties, the E. Howard Watch and Clock Company succeeded the old company, the capital being placed at $250,000. In 1882 Mr. Howard severed his connection with the company and retired from active business. He died March 5, 1904. In 1900 the clock manufacturing and the watch manufacturing were separated. Clocks are manufactured at the old stand under the firm name of "The E. Howard Clock Co." The right to manufacture the Howard watch was sold to the Keystone Watch Case Co. of Philadelphia, which was organized in 1899. The factory of the United States Watch Co. at Waltham was purchased and the Howard watch has been made there since about 1903. This factory is situated on the opposite side of the Charles River from the Waltham Watch Co. The firm name is "The E. Howard Watch Works." Although not one of the largest in the country this firm has been noted for the excellence and accuracy of its output. The total number of watches made to date (1922) is about a million and a half. All the watches are cased at the factory and no watch is made with less than 17 jewels. They are all adjusted to temperature and isochronism, and to five or three positions, depending upon the grade.

As was previously stated, the Boston Watch Co. failed in 1857 and the reorganized firm was known as Tracy, Baker & Co. Tracy and Baker soon sold out their interest

and Mr. James Appleton became associated with the firm under the name of Appleton, Tracy & Co. On February 8, 1859, the name of the company was changed by act of the legislature to "The American Watch Company." On May 19, 1860, the capital stock was increased to $300,000 and in the same year a dividend of 5 per cent was declared. This was the first dividend ever declared on watchmaking in America. In 1859 some of the leading men left the Waltham factory to found a new watch factory at Nashua, N. H. This lasted but three years and in 1862 the entire stock was purchased by the Waltham Company and moved to Waltham. Some of the men were also given positions in the Waltham factory. In 1861 the first ladies' watch ever manufactured in America was turned out. It was 10-size and key wind. In 1885 the capital stock was increased to $4,000,000 and the name was changed to "The American Waltham Watch Co." From time to time additions were made to the factory and the capital stock was increased, until at present the capital stock is $12,000,000. In 1906 the firm name was changed to the Waltham Watch Co., and in 1913 the company purchased the business of the Waltham Clock Co. At present there is a giant factory five stories high, with a frontage of nearly 800 feet and several wings. The building is of brick and steel construction with many windows. The last of the original buildings was demolished in 1879. In Fig. 281 are shown three views of the factory at different times and they illustrate three stages of progress. The first is the original factory in 1854. The second shows the factory in 1880 and the third pictures the present enormous building. There are now about 3000 to 4000 employees and the average output is about 2000 watches a day. The employees are high grade and well taken care of. The factory is kept very clean, it is well ventilated and heated, there are rest rooms and lunch rooms and many provisions for the health and welfare of the employees. Since the output of the factory is so large, all grades and sizes of watches are made. Up to 1884 the total number of watches manufactured was about 2,500,000; up

FIG. 281. — THREE STAGES OF PROGRESS IN THE WALTHAM WATCH CO.

to 1894, about 5,900,000; up to 1904, about 12,000,000; and at present (1922) the total number is nearing 25,000,000.

The watch factories of today are not numerous. The census of 1900 takes account of only 12. In fact there are not more than 8 or 10 large watch factories in the country. The following list (in alphabetical order) contains most of the large and important firms:

The Elgin National Watch Co., Elgin, Ill.
Hamilton Watch Co., Lancaster, Pa.
The Dueber-Hampden Watch Co., Canton, Ohio.
E. Howard Watch Works, Waltham, Mass.
Illinois Watch Co., Springfield, Ill.
R. H. Ingersoll & Bro., 415 Fourth Ave., New York City.
New York Standard Watch Co., Jersey City, N. J.
South Bend Watch Co., South Bend, Ind.
The Waltham Watch Co., Waltham, Mass.

It will be noticed that there are only a few states in which there are watch factories. Illinois and Massachusetts lead not only in the number but also in the size of the factories. The two largest factories are the Elgin and the Waltham.

The Gruen Watch Manufacturing Co., of 31-A East Fifth Avenue, Cincinnati, Ohio, and Madre-Biel, Switzerland, should perhaps be mentioned here. It is generally understood that the watch parts are manufactured at Madre-Biel and imported as parts and that these parts are assembled and the watch adjusted at Cincinnati. They have specialized along the lines of artistic and very thin watches. The founder of the firm is Dietrich Gruen, a Swiss watchmaker, who came to America in 1876, married here, and founded the firm.

Shortly after 1860 [1] John C. Adams, a practical American watchmaker, conceived the idea of locating a watch factory in the Middle West. His enthusiasm resulted in interesting Benjamin W. Raymond, a prominent capitalist and

[1]Taken almost word for word from an interesting advertising pamphlet entitled "The Watch," issued by the Elgin National Watch Co. in 1917.

former mayor of Chicago, who had business connections in Elgin, Ill., then a town of only 3200 people. With George B. Adams, a retail jeweler of Elgin, they secured factory site concessions and incorporated the National Watch Company with a capitalization of $100,000. Mr. Raymond was elected the first president. The organizers searched the East for mechanical experts and secured Charles S. Moseley and George Hunter. In January, 1865, a three-story

Courtesy, The Elgin National Watch Co.

FIG. 282. — THE ELGIN WATCH FACTORY.

wooden building, 30 × 60 feet, was put up on the banks of the Fox River in the business district of Elgin. Here the company began the manufacture of watchmaking tools and machinery. Meanwhile permanent factory buildings were being built on the company's property south of the main business district. On the first day of 1866, the machine department moved into its new building. Within six months the entire organization was at work in the new factory. In April, 1867, the first watch was sent out. This pioneer model was named the B. W. Raymond, in honor of the

President. It was 18-size, key wind and set, with single roller escapement and 15 jewels. These watches retailed for $117 without the case. Since 1874 the firm name has been "The Elgin National Watch Co." At the present time the factory covers about 24 acres of floor space and there are more than three thousand employees. The daily output is about 3100 watches. The total number of watches manufactured to date (1922) is about 25,000,000. It is a model factory and careful attention is given to light, heat, ventilation, and the welfare of the employees. It is pictured in Fig. 282. Mr. Charles H. Hulburd has been president of the company since 1898. In Fig. 283 is pictured the observatory connected with the Elgin Watch factory where exact time is determined by star observations for use in the factory.

FIG. 283.—THE OBSERVATORY OF THE ELGIN WATCH FACTORY.

The plant of the Hamilton Watch Co. is at Lancaster, Pa., and its beautifully located factory is shown in Fig. 284. Hamilton watches were first manufactured in 1892, although a watch factory has existed at Lancaster since 1874. At present there are

FIG. 284.—THE HAMILTON WATCH FACTORY, AT LANCASTER, PA.

32 different models ranging in size from 6/0-size to 18-size. No watch is made with less than 17 jewels. There are about 750 employees and about 350 watches are produced each day. The total number to date (1922) is nearly 2,000,000.

FIG. 285. — THE DUEBER-HAMPDEN WATCH FACTORY.

The magnificent factory of the Dueber-Hampden Watch Co. of Canton, Ohio, is pictured in Fig. 285. The movement is usually marked "Hampden Watch Co." and the case is marked "Dueber." It is a consolidation of two companies. The cases for the movements are all made in the same factory and every watch is sold cased. In 1864 John C. Dueber was making watch cases at Cincinnati, Ohio. He made them so well that his business rapidly increased. A new brick building was next erected across the river at Newport, Ky. In 1886 Mr. Dueber perfected an alliance with the Hampden Watch Co. of Springfield, Mass. The history of the Hampden Watch Co. really begins in 1864. It was then that the Mozart Watch Co. was organized with a capital stock of $10,000 and an office and factory in Providence, R. I. In 1866 the name of the company was changed to "The New York Watch Co." and the machinery was moved to the new factory in Springfield,

Mass. A disastrous fire and the panic of 1873 caused several reorganizations and finally in 1887 the company was known as the Hampden Watch Co. As was previously stated, the alliance between Mr. Dueber and the Hampden Watch Co. was perfected in 1886. A tract of land in the growing city of Canton, Ohio, was secured and upon this ground were erected the buildings of what is now the great Dueber-Hampden Watch Company. The output to date (1922) is nearly 3,000,000 watches.

The Illinois Watch Co., the makers of the Illinois-Springfield movement, is located at Springfield, Ill., and a

FIG. 286.—THE WATCH FACTORY OF THE ILLINOIS WATCH CO.

picture of the factory is shown in Fig. 286. The company was organized in January, 1869, with a capital of $100,000. Work was commenced on the factory in 1870 and the first watch was turned out in 1872. It was 18-size, full plate, and key wind. The company has been reorganized and the name slightly changed several times since. At present there are fourteen acres of ground in use and about 1200 employees. The daily output is some 700 watches and the total output to date (1922) is in the neighborhood of 4,000,000 watches. This company adjusts some of its best watches to six positions instead of five, which is the usual number. A picture of the observatory connected with the factory is shown in Fig. 287.

The factory of the South Bend Watch Co. is shown in Fig. 288. This firm has produced about 1,000,000 watches.

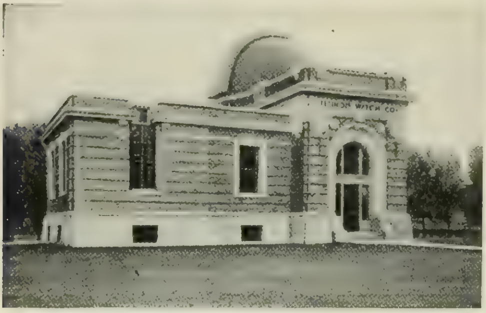


FIG. 287.—THE OBSERVATORY OF THE ILLINOIS WATCH CO.

Nearly all of the watches made by R. H. Ingersoll & Bro. are the very inexpensive watches ranging in price (retail 1920) from about $12 down. There are about a dozen models at present. Among the older models is "the watch that made the dollar famous." Until very recently, they had no jewels. They were more like little sturdy alarm clocks than watches. Now some have four and some seven jewels. To have four jewels means that the balance staff has hole jewels and end stones. The roller jewel and pallet jewels are steel pins unless the watch has seven jewels.

The first attempt to make a cheap watch dates from 1875, when Jason R. Hopkins of Washington, D. C., perfected a model of a watch which he thought could be constructed

FIG. 288.—THE FACTORY OF THE SOUTH BEND WATCH CO.

for fifty cents. He tried to interest various people in the project and finally secured the assistance of W. B. Fowle, of Auburndale, Mass. It was a complete failure and Fowle and the watch company both made assignments in 1883.

The second attempt to make a cheap watch resulted in the ever-remembered long-winding Waterbury watch. The foundation patent for this was issued May 21, 1878, to D. A. A. Buck, a watchmaker of Worcester, Mass., who devised the watch after many months of patient effort. Then came the struggle to interest capital. The funds and manufacturing space were for the most part provided by the Benedict and Burnham Manufacturing Co. of Waterbury, Conn. For this reason it was called the Waterbury watch. The quarters were too small, so the Waterbury Watch Co. was organized and a new factory built. It was 1880 before the first watches were produced. After certain minor difficulties were overcome, they proved to be a success. By 1888 the output had increased to nearly 500,000 a year. The watch was quite simple and had only fifty-eight parts. The spring was nine feet long and coiled around the movement just inside the case which served as the barrel. The old duplex escapement was used, improved, however, so that it could be cheaply stamped out. The whole movement carrying the minute hand with it turned round once every hour. The dial was printed on paper, covered with celluloid, and glued to the plate. It was sold for the then small price of $4. They were often given away with suits of clothes as a premium. The rather remarkable thing is that after a time there seemed to be less demand for them. The Waterbury Watch Co. finally abandoned the watch, reorganized as the New England Watch Co., and began making other watches. This company failed in 1914 and was bought out by R. H. Ingersoll & Bro. It is now one of the three places where Ingersoll watches are made.

It was about 1892 or a little earlier that R. H. Ingersoll & Bro. got the idea of going into the inexpensive watch business and pushing their sale. At that time cheap watches, or perhaps we should call them small alarm clocks, were being made by the New Haven Clock Co. and by the Waterbury Clock Co. at Waterbury. The latter was the smaller. Ingersoll contracted for several thousand of these and listed them in his mail-order catalogues for 1892 for

the first time. The price was *one dollar*. They proved a success and the sales increased rapidly. Later a contract with the Waterbury Clock Co. was entered into whereby the factory was to produce the goods under the name of the Ingersolls. This arrangement continues at present. In 1908 R. H. Ingersoll & Bro. purchased the factory and business of the Trenton Watch Co., at Trenton, N. J., which had been organized in 1885, and began making watches on their own account. Thus Ingersoll watches are made in three places: in the factory of the Waterbury Clock Co., in their own factory at Waterbury, Conn., and in their own factory at Trenton, N. J. The present output is about 20,000 watches a day and in the twenty-five years of their experience they have put out about 50,000,000 watches. They have literally put a watch into every man's pocket.

The firm consists of two brothers, Robert Hawley Ingersoll and Charles Henry Ingersoll. The founder and president, Robert H. Ingersoll, was born at Delta, Eaton County, Mich., December 26, 1859. In 1879, at the age of twenty, he came to New York City and the next year engaged in the business of manufacturing rubber stamps. Later he established a mail-order business, selling many specialties. It was in 1892 that the "dollar watch" was added.

Charles H. Ingersoll was born at Delta, Eaton County, Mich., October 29, 1865. At the age of fifteen he entered the employ of his brother in New York. Since 1880 he has been associated with him in the firm R. H. Ingersoll & Bro.

Very recently (winter, 1922) the firm R. H. Ingersoll & Bro. has failed. The interests of this firm, in watches at any rate, have been purchased by the Waterbury Clock Co. It will be remembered that this clock factory was one of the three places where Ingersoll watches were made.

If all the watch manufacturing companies which have existed in the United States from 1850 to date were listed, the list would be several times as long as that of the firms existing at present. Most of these firms lasted but a few years. They either failed and went out of existence or

were reorganized under a different name. If one were to go over the checkered history of all these firms, two decided impressions would be gained. First watchmaking has been financially a dismal failure. But one has made good where four have failed. In the second place, one is struck with the almost kaleidoscopic rapidity with which companies were organized, failed, changed their names, and began manufacturing elsewhere.[1]

If one were to examine the watches offered for sale by any large jeweler, one would find on the dials many names besides those of the watch factories which have just been mentioned. It may be the name of some smaller watch factory or some one of the many watch factories which have now gone out of existence. Perhaps it is an imported watch and the name is that of some foreign maker. Perhaps it is the name of some jeweler. More likely it is a trade name. Many jewelers have the custom of having their own name instead of the name of the watch factory placed on the dials of the watches which they sell. By opening the back of the watch and inspecting the movement the name of the watch factory which made it can usually be ascertained. Trade names are in quite common use. Some of the large American watch factories put out watches at times under trade names. It may be a request and it may be to disown the product. Trade names are also often used on poor, cheap Swiss watches The converse of this proposition is, however, not true, for the presence of a trade name does not necessarily mean that the watch is of inferior grade.

The making of a watch in a modern watch factory is most interesting. It is not easily described and must be seen to be appreciated. If one has a chance to visit a big modern watch factory, it is an opportunity which should not be neglected. It will mean a trip of a mile or two through many departments and in a maze of automatic machinery.

[1] More detailed information about the companies may be obtained if desired from: ABBOTT — *The Watch Factories of America;* BREARLEY — *Time Telling Through the Ages;* BAILEY — *Through the Ages with Father Time.*

There will be a feeling of bewilderment at the end, but it will have been a very interesting and educational trip.

There are between 150 and 200 parts in a modern watch and about one third of these parts are screws. It is variously stated that it requires from 3700 to 4000 operations to construct a watch. These operations are performed, as far as possible, by automatic machines and one single machine usually performs many, perhaps hundreds of operations. If a watch of a new model is to be constructed, the first thing is to make accurate drawings of the watch and all its parts. These are then taken to the tool shops and the machine shop and here must be constructed the tools and automatic machines for making the parts. It is not surprising then that the tool and machine shops are an important part of a watch factory. Usually about one tenth of the total number of employees is to be found here. These machines are ten times as complicated and intricate as the watches themselves, and require highly skilled mechanics. Several thousand different kinds of hand tools are usually made in the tool shop.

We now come to the making of the watch itself. The foundation of a watch is the pillar plate, that is, the plate next the dial. Metal discs of the right size and thickness are first stamped out. These then go to the plate department. Here they must be milled, drilled, tapped, recessed, etc. It will be remembered that the other parts of a watch are attached to this pillar plate. Thus all these perforations and indentations must be made. Here is a description of one of these automatic machines, used at the Elgin factory.[1]

The most amazing of these automatics is one which drills, taps and countersinks the holes in the pillar plate, the foundation of the watch. This one machine, which was invented and perfected in the Company's machine shop in about three years' time, automatically performs 85 operations at one setting. It looks like a glass barrel, stood on one end and flooded with jets of oil. It comprises over 14,000 separate parts, three times as

[1] Taken from "The Watch," an interesting advertising pamphlet issued by the Elgin National Watch Co.

many as a modern locomotive, and is made up of 36 smaller machines, arranged in pairs so as to work on both sides of the watch plate at once.

These 36 units are arranged in pairs at regular intervals, or stations, around a cylindrical frame. An automatic carrier holding 21 blank watch plates stops at the first station. Tools from the twin units engage the plate from above and below, backing off again when their work is done. The carrier moves on to the next station, where other tools are brought into play — till the watch plates have run the gauntlet of all twenty stations and are discharged at the place of beginning.

In this almost uncanny machine there are 320 gears, and some of them make 7000 revolutions per minute. It is under electric control. If a tool breaks, the machine automatically stops and flashes a light to show which station needs attention. The whole machine is so novel and so complicated in design that skeptics freely predicted it would never work, but time has proved it one of the most efficient machines the Company has yet invented. Behind its veil of oil-spray it performs its manifold operations with super-human precision.

In the same way, the bridges or other plate of a watch are made.

The parts of a watch are mostly stampings or turnings. The plates, bridges, wheels, levers, etc., are first stamped out and then finished. The axles, screws, etc., are turned out from rods or wire. An interesting example of turning out an axle is the balance staff machine. The balance staff or axle is the one which is the most complicated and requires the most exact work. The following is an interesting account of the machine.[1]

It is in these turning operations, perhaps, that we find the greatest ingenuity and the greatest interest. For it is here that the most marvelous automatic machines of all with their seemingly human intelligence are to be seen.

As a typical example of such a machine, examine the workings of one of the automatic marvels which makes balance staffs,

[1] Taken from "The Making of a Marvelous Mechanism," an interesting advertising booklet issued by the South Bend Watch Factory.

the part of the watch that forms the axis for the balance wheel and plays a very important part in correct time-keeping.

A machine that takes a piece of highest grade carbon steel wire about three feet long and without human assistance of any kind fashions from it 150 of the finest balance staffs in the world, each one an exact duplicate of every other, certainly may be said to closely approximate human intelligence in its performance.

Yet that is exactly what this machine continues to do hour after hour, and the manner of its workings still further impresses the observer with the evidence of an almost uncanny intelligence.

This machine occupies a space but little larger than an ordinary typewriter and is a marvel of efficiency, probably not exceeded by any other piece of mechanism in existence.

Ten cutters are mounted on a centrally located axle which can be timed to make almost any sort of cut by means of shifting cams on a large cylinder beneath. This cylinder is provided with a large number of lobes and by changing the combination between cams and lobes about one thousand different operations may be obtained.

The balance staffs produced by this machine are made direct from the wire ready for hardening with no other human directions than those given by the men who arranged the combination of cams and lobes. Each separate shoulder on the staffs has both a rough and finished cutter, producing a class of work impossible on the ordinary machine where roughing and finishing is done with the same cutter. There are six shoulders and all of them are made to gauge to the $\frac{1}{2500}$th of an inch. The fact that the entire balance staff is completed from the wire while held absolutely rigid in one position insures a truth of alignment that is absolute.

This remarkable machine, in addition to its skillful performance, displays intelligence in another interesting way. When the end of the wire is reached or if an accident to the piece occurs or the machine itself gets off standard, it automatically stops work and rings a bell summoning a mechanic so that the trouble may be remedied immediately. The pulley which drives the spindle revolves on ball bearings at a speed of 4500 revolutions per minute. Three mechanical principles are used in its operation: compressed air, electric contact, and motor drive. All screws, pinions, jewel settings, etc., are made in much the same manner and by machines very similar to that just described. Batteries of these machines which act with the same marvelous superhuman skill

range in long lines down the entire length of several departments of the factory and are continually at work eating up rods of steel and brass and converting them into watch parts of extreme delicacy, minuteness, and exactness.

This machine is pictured in Fig. 289.

The screws used in a watch are of all sizes, some of them so small that they cannot be well seen without a microscope and it requires 563,000 of them to weigh a pound. And yet each one must have a perfectly slotted head and an evenly-cut thread. These are all made by automatic machines. One of the screw-making machines invented by E. A. Marsh and used in the Waltham Watch factory is pictured in Fig. 290. It must not be supposed that a watch factory possesses but one of each kind of these automatic machines. A large factory will have whole rooms full of one kind and more besides. In Fig. 291 is shown one of these "automatic rooms" in the Waltham factory.[1]

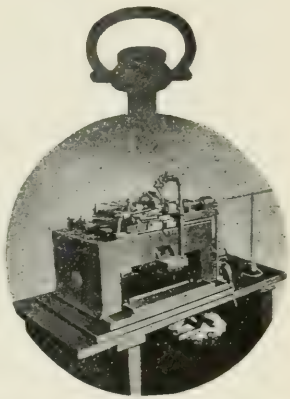


FIG. 289. AN AUTOMATIC BALANCE STAFF MACHINE.
(The South Bend Watch Co.)

Although all the parts of a watch are practically interchangeable, that is, the same in all watches of the same size and model, nevertheless certain parts are made for one particular watch. To make this possible the pillar plate and bridges as soon as they are finished are given a serial number which is stamped into them with dies. A watch may then be said to have been born. In the future if certain parts are fitted to one particular set of plates, they eventually become part of that watch and no other. This is accomplished by using numbered trays ordinarily holding ten parts. Thus, however widely these

[1] Taken from "Workers Together," an interesting advertising booklet issued by the Waltham Watch Co.

parts may become separated as they undergo different operations, they nevertheless meet again and become part of the same watch. An application of this special fitting of parts is here illustrated.

The skill with which these jewels are put into their settings and the shoulders cut so as to provide just the proper amount of play between jewel and pivot furnishes another example of skill

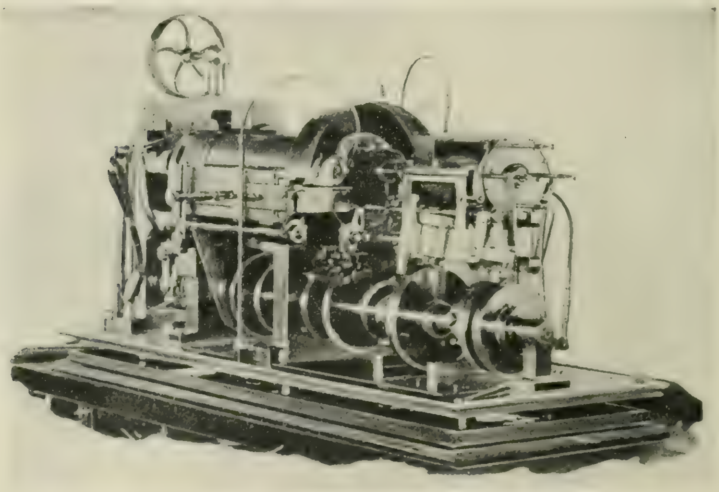


FIG. 290. — A SCREW-MAKING MACHINE.

(From MARSH, *The Evolution of Automatic Machinery.*)

and accuracy that pen or type fail to depict. An ingenious machine is used for this purpose. The plate of the watch is placed in it, the staff and wheel for which that particular jewel is designed, placed between other bearings and the resultant sum of these distances actuates the machine in such a way that it cuts a shoulder on the jewel setting at the point indicated as giving the proper amount of play.

In a somewhat similar way the jewel itself acts as a pattern on another ingenious machine called a caliper rest, so that a boring is made in the jewel setting just large enough to hold that individual jewel in place.

Dial making is also interesting.

The base of each dial is a disc stamped out of pure copper. Then fine white glass enamel ground to a powder is sifted upon the copper disc. It is then subjected to an intense heat in a furnace which fuses the enamel and causes it to flow evenly over the copper. Then the hours, minutes, and other markings are stamped upon it by a method similar to that used in name card engraving. A steel plate having the numerals engraved in it has

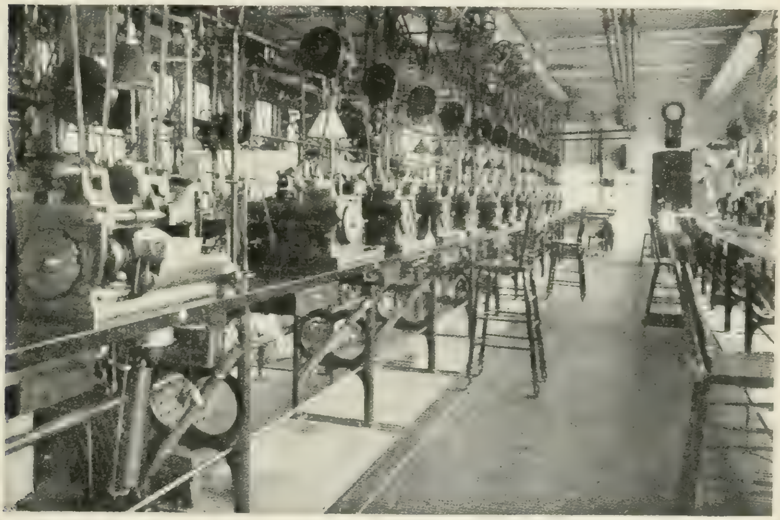


FIG. 291.—ONE OF THE "AUTOMATIC ROOMS" IN THE WALTHAM FACTORY.

the depressions filled with a black enamel. A rubber pad then comes in contact with the steel plate, the black enamel adhering to the rubber, which then transfers it to the dial. This operation is repeated in order to get a permanent brilliancy and the dial is again placed in the furnace to have the numerals fused.

The depression which you will observe about the second hand of your watch and another in the center of the dial if your watch happens to be equipped with a double-sunk dial are formed by stamping these parts out separately, treating them the same as the main part of the dial already described and then soldering these pieces carefully together. So that one such dial is really a combination of three separate dials.

It will now be assumed that the 150 to 200 parts of a watch have been made. They have been stamped out or turned out, they have undergone a great variety of operations, and have been decorated and finished. It now remains to assemble the watch. The order of procedure may not be quite the same in different watch factories but the differences are small. If it is a full plate movement it is more convenient to assemble on the top plate. In the other forms it is done, of course, on the lower plate. First the banking screws and mainspring are put in. Next the wheels which constitute the train are put in. The jewels have already been set while the plates were under construction. Finished screws are now used. If the parts were held together during manufacture, service screws were used. The reason for this was to avoid marring the screws which were finally to be used. Next the stem winding and setting mechanism is fitted and the cannon pinion put in. Here again service or substitute winding wheels are usually put in to save the mirror polish on those to be used finally. Next the roller jewels and pallet jewels are set; in short, the escapement is put in order. The balance is trued and poised and a hairspring chosen for it. The watch is now oiled and the regulator put on. Next it receives the dial and hands and motion work. It is now a complete watch and ready to run. It is adjusted to temperature first. This is done by exposing it to a temperature of from 35 to 40 and also to a temperature of from 90 to 100F. The balance is again poised and all service parts are now replaced by the permanent parts. The watch is next adjusted to position and isochronism. It has now passed through all the various operations and tests and is ready to be sold. It requires from six months to a year to construct and test a good watch. If the daily output of a watch factory were about 1000 watches, then one would expect to find about 300,000 watches in the factory in various stages of manufacture.

It would not be proper to finish this subject without at least mentioning by name some of the master mechanics

whose inventive genius has modeled and constructed not only watches but the far more wonderful automatic machinery for making them. It is usually claimed that the model of the first watch for Dennison and Howard was made by Oliver Marsh and David Marsh. Charles S. Moseley, James Baker, N. P. Stratton and James T. Shepard may have helped, as they were early connected with the pioneer factory. Some of them continued at the watchmaking business all their lives. Others dropped out early. Among the later master mechanics chiefly at the Waltham and Elgin factories may be mentioned: Duane H. Church, Charles Vander Woerd, E. A. Marsh, N. B. Sherwood, Patten S. Bartlett, George Hunter, Ambrose Webster, Charles W. Fogg.

It would hardly be practicable or interesting to take up the lives and inventions of each of these famous men, but they have all contributed much to the progress and astounding development of watchmaking in America.

The cost of watches. — The most expensive watch made in this country is the $750 presentation watch made by the Waltham Watch Co. of Waltham, Mass. It is claimed that it is the equal, if not the superior, of any watch made in the world. This watch has been fully described and pictured on page 120. The price includes the movement and a handsome and appropriate solid gold case.

Next in price comes "the best watch" made by any one of the large firms. It will have 21 or 23 jewels. Some claim that 21 jewels are sufficient and do not put more in their very best watches. It will be adjusted to temperature, isochronism, and five positions. It will be 18-size or 16-size, or perhaps even 12-size. In an appropriate solid gold case it will sell somewhere between a little more than $150 and somewhat less than $300. A 17-jewel movement adjusted to temperature, isochronism, and to three or five positions in a gold-filled case can be procured for $30 to $50. A 7-jewel watch in an inexpensive appropriate case costs in the neighborhood of $15. These are all approximate 1922 prices.

Watch cases. — The manufacture of watch movements and the manufacture of watch cases are two entirely distinct industries. In extremely few instances are the cases made in the same factory which manufactures movements. Quite a few firms which manufacture watch movements sell only complete watches, that is, movements in their cases. Most firms sell movements only or a cased movement in accordance with the wish of the purchaser. This means that they procure their cases from one or more of the firms which make only watch cases.

The number of firms making watch cases is about three times as large as the number making watch movements. In 1900, according to the census, there were 13 firms making movements and 30 making cases. The value of the product is about the same. In 1900 the manufactured watch movements were worth $6,823,611, while the cases were worth $7,783,960.

Watch cases are of two kinds, "open-face" and "hunting." Of these the hunting cases are usually a little more valuable because more metal is required in their construction. The trend of fashion at present seems to be towards open-faced watches.

Watch cases may also be classified in accordance with the material of which they are made. In the census reports they are classified as gold, gold-filled, silver, silverene, and other kinds. The gold-filled case was invented and patented by James Boss of Philadelphia in 1859. Under silverene is classed all cases made of any alloy which looks like silver. Under other kinds would be classed gun metal, nickel, plated brass, and the like. Enameled cases and those set with gems are not here considered.

Modern watch cases are decorated in three ways. They are plain polished, engine turned, or engraved. Many combinations of these ways are, of course, used. These three ways are illustrated in Fig. 292.

Statistics on the manufacture of watches. — This chapter, like the preceding one on the manufacture of clocks, will close with some statistics on the manufacture of watch

FIG. 292. — WATCH CASES ORNAMENTED IN THE THREE MODERN WAYS — PLAIN POLISHED, ENGINE TURNED, AND ENGRAVED.
(The Howard Watch Co.)

movements and watch cases. The sources from which the figures were taken are the same as those mentioned in the other chapter. It should be mentioned, perhaps, that Vol. X of the Twelfth Census of the United States (1900), Part IV, Manufactures, contains a special article on watches and watch cases. This gives much more information than the (last) Thirteenth Census (1910). In the previous chapter were also given some statistics relating to timekeepers in general, that is, to clocks and watches including cases and materials. The figures here given refer to watch movements and watch cases only. When the term "watch" is used, it is to be understood that unless otherwise stated it refers to the movement only.

Table I gives various facts about the 13 firms making watch movements and the 30 firms making watch cases. They are for the census year 1900 and apply to the United States. It will be noticed that there are more than twice as many watch case firms as watch firms. The value of the product is, however, about the same. It is interesting to note that the average value of a watch movement (obtained by dividing the value of the product by the number manufactured) at the factory is between three and four dollars. The average value of a watch case is between four and five dollars. Thus, in 1900, the average value at the factory of a complete cased watch was about eight dollars.

Table II gives comparative figures for watch movements for various years. It will be seen that the number of firms has greatly decreased, but that the value of the product is nearly ten times what it was forty years ago.

Table III gives similar comparative figures for watch cases. Here the decrease in the number of firms is not so marked.

Table IV gives the distribution by states of the 13 watch factories and the 30 watch case factories in 1900. It is remarkable how few states are represented.

Table V gives figures concerning the different kinds of watch cases in 1900. It will be noticed how the gold-filled case leads all the others.

Table VI shows the relative size of the watch and watch case establishments in 1900. Watch factories tend to be large. Watch case factories are often small.

Table VII gives figures as regards the exports and imports of watches. Cases are here included. It will be seen that about one twenty-fifth of the product is exported. Imports are much above exports. Of the imports those from Switzerland constitute about 70 per cent; those from France about 10 per cent; those from Germany 8 per cent; and those from Great Britain about 6 per cent.

In these tables low-priced (dollar watches and the like) are not included. These were then made almost exclusively in clock factories as a by-product. In 1900 1,211,662 of these watches were manufactured (valued at $566,147) and 703,249 watch cases (valued at $74,860). During the last twenty years the number of these low-priced watches has increased tremendously. Now (1920) about as many of these low-priced watches have been made by one firm as of all other kinds by all other firms put together.

TABLE I

Summary of the United States for 1900

	Watches	Watch Cases
Number of establishments	13	30
Capital	$14,235,191	$8,119,292
Salaried officials	165	235
Salaries	$294,449	$289,366
Wage earners	6,880	3,907
Wages	$3,586,723	$1,924,847
Value of products	$6,822,611	$7,783,960
Number manufactured	1,825,769	1,719,362

TABLE II

Watch Movements

	Number of Establishments	Capital	Wage Earners	Wages	Cost of Materials	Value of Products
1919	18	$59,000,742	15,888	$16,598,896	$6,392,562	$32,044,299
1914	15	36,388,700	12,390	7,524,146	2,669,511	14,275,279
1909	13	. . . .	10,684	6,085,700	2,185,825	11,771,065
1904	14	. . . .	10,724	6,024,400	2,258,683	11,866,400
1899	13	14,235,191	6,880	3,586,723	1,291,318	6,822,611
1889	19	10,106,114	6,595	3,587,808	995,740	6,051,066
1879	11	4,144,327	3,346	1,712,276	982,224	3,271,244
1869	37	2,666,133	1,816	1,304,304	412,783	2,819,080

TABLE III

Watch Cases

	Number of Establishments	Capital	Wage Earners	Wages	Cost of Materials	Value of Products
1919	33	$21,790,556	3,900	$4,000,727	$8,205,754	$19,618,773
1914	31	11,220,024	3,514	1,938,358	4,001,595	7,830,987
1909	29	. . . .	4,569	2,428,262	5,034,377	10,514,854
1904	28	. . . .	4,221	2,170,507	4,428,627	8,626,504
1899	30	8,119,292	3,907	1,924,847	4,393,647	7,783,960
1889	45	4,727,100	3,679	1,896,587	5,022,455	8,618,479
1879	27	1,584,740	1,758	976,041	2,812,922	4,589,314
1869	49	730,500	703	555,018	1,152,979	2,333,340

TABLE IV

Watch Establishments in 1900

Illinois	3	New York	1
New Jersey	3	Connecticut	1
Massachusetts	2	Pennsylvania	1
Ohio	2		—
		Total	13

Watch Case Establishments in 1900

New York	13	Massachusetts	2	Maryland	1
New Jersey	5	Ohio	2	Kentucky	1
Illinois	4	Pennsylvania	2		—
				Total	30

TABLE V

WATCH CASES: KIND, NUMBER, AND VALUE IN 1900

	Number	Value
Gold	233,993	$3,170,629
Silver	171,837	461,882
Gold-filled	748,735	3,187,103
Silverene	356,126	233,391
Other kinds	208,671	122,152
Total	1,719,362	$7,175,157
Other products		608,803

TABLE VI

NUMBER OF EMPLOYEES IN 1900

	Establishments with This Number	
	Watches	Watch Cases
Under 5	1	2
5 to 20	1	9
21 to 50	1	5
51 to 100	1	3
101 to 250	2	4
251 to 500	3	3
501 to 1000	2	2
Over 1000	2	1
	13	29

[1] One not included.

TABLE VII

Watches and Parts	1905	1906	1907	1908	1909	1910
Imported	$2,479,730	$2,565,343	$2,983,113	$2,451,009	$2,088,034	$1,869,402
Exported	1,124,168	1,293,990	1,723,982	1,386,736	1,251,537	1,228,713

TABLE VII — *Continued*

Watches and Parts	1911	1912	1913	1914	1915	1916
Imported . .	$2,293,679	$2,313,677	$2,615,744	$3,386,738	$3,039,651	$3,362,728
Exported . .	1,560,870	1,880,677	1,783,249	1,460,424	914,776	1,524,438
Exported imports	2,652	7,618	5,261	3,859	3,211	10,055

Watches and Parts	1917	1918	1919 [1]	1920	1921
Imported . .	$5,691,852	$9,371,570	$12,646,725	$15,688,233	$9,168,605
Exported . .	1,744,133	1,944,501	2,273,045	2,145,463	819,043

[1] Calendar year, not to June 30, as in figures for 1905 to 1918, inclusive.

CHAPTER XXII

MODERN EUROPEAN WATCHMAKERS

In the previous chapter on the "History of Watchmaking in America," considerable space was given to the more important of the modern watch factories. Their history, development, and present condition were quite fully presented. It now remains to devote a little space to modern European watchmakers. It will be seen that both this chapter and the previous one have to do with the industrial rather than the inventive side of watchmaking.

By 1800 the modern watch had been invented. It was an accurate timepiece and the last century has seen but very few changes in it. During the last century the industry has developed tremendously and a watch has been put into every man's pocket. Formerly it was an article of luxury and for the very few.

Of the watches imported into the United States about three fourths come from Switzerland. A very few come from England, France, and Germany. These are the countries, then, which need consideration.

Watchmaking in England. — Until about 1800 all watches were individually made. The master watchmaker could and often did make all the parts, assemble them, and adjust the completed watch. He usually had a number of apprentices and workmen. The English watch was substantial and reliable but expensive. It was produced without regard to cost. Later watchmaking became what might be called a household industry. This resulted from the division of labor. One person would make one part and some one else another. The work was often done at home and even at odd times. All this could never lead, of course, to mass production, but the quality remained high.

Later machinery was more and more used and still later it was power-driven. English watchmaking has always been characterized by conservatism and extreme reluctance to make any changes either in the construction of a watch or in methods of manufacture. Thus the fusee continued to be used until nearly the end of the nineteenth century, although the Swiss had long since discarded it and it had never been used in America. They have been equally slow to use power-driven automatic machinery, to place it in one factory, and to employ women operatives.

Sir Edmund Beckett, in his excellent book, *Clocks and Watches and Bells* (this was written about 1880), says in different places: "There are accounts of some of these factories,[1] where watches are made by machinery, so that every piece will fit every watch of the same pattern. . . . To a certain extent the same thing is done at the celebrated watch factory of Messrs. Rotherham at Coventry, and also at Prescott in Lancashire, where watch movements, i.e., the train set in a frame, are chiefly made. . . . Although labour is dearer in America than here, this machinery enables them to undersell English watches of the same quality, as the Swiss also do with cheaper labour and more organization, though with less use of machinery; and if our English makers do not bestir themselves they will lose the trade in all but the best watches, as they have already lost that of both cheap and ornamental clocks." It might be added that his prophecy has practically come true. The English watch has remained heavy, substantial, reliable, but not cheap.

Individual English watchmakers are not well known in America. Three firms which make very high grade watches but in small quantities are: E. Dent & Co., Ltd., 61 Strand, London; V. Kullberg, 105 Liverpool Road, London, N.; and Chas. Frodsham & Co., Ltd., 27 South Molton Street, London, W. I. These firms make chronometers and precision clocks also and are probably better known along these lines than as makers of excellent watches.

[1] American watch factories.

Edward John Dent, the founder of the firm E. Dent & Co., was born in 1790. Early in life he was apprenticed to a tallow chandler but did not like the business. He induced Richard Rippon, in whose house he lived, to instruct him in making the repeating mechanism of watches. In 1830 he joined J. R. Arnold in partnership at 84 Strand. After ten years the partnership expired and Dent established himself at 82 Strand and afterwards removed to 61 Strand. He also had two other shops in London. He married the widow of Richard Rippon and her two sons, Frederick and Richard, took the name of Dent. He made the tower clock which was fixed in the tower of the Royal Exchange in 1844. As has already been related in another chapter, he received the contract in February, 1852, for making the Westminster clock. E. J. Dent died in 1853 and the business in the Strand was taken over by Frederick (Rippon) Dent, who died in 1860. The firm has had the care of the Westminster clock since it was placed in the tower. They also constructed the chief astronomical clock of the Greenwich Observatory. The present firm name is still E. Dent & Co., and the Dents are still chiefly active in the firm. The head office is 61 Strand and there are two branches: at 4 Royal Exchange, E. C., and 34 Cockspur, W. The total number of clocks and watches to date (1921) is something over 60,000, and the watches are all hand made. Some are intricate watches with many attachments.

Victor Kullberg was born at Wisby, on the island of Gothland, Sweden, in 1824. He came to London in 1851 and died there in 1890. He was known as a brilliant and successful maker of timekeepers. His chronometers were particularly successful in the Greenwich tests. As the firm states in one of its advertisements, Kullberg chronometers have stood first or second fifty-two times at the yearly competitive trials at the Royal Observatory, Greenwich. The present firm makes high grade watches and astronomical clocks, as well as chronometers.

The firm Chas. Frodsham & Co. was founded by William Frodsham, who learned watchmaking from the celebrated

Earnshaw. He was born in 1728 and died in 1807. The business was carried on by his son and then by his grandson, W. J. Frodsham. This William James Frodsham was born in 1778, admitted to the Clockmakers' Company in 1802, was master in 1836 and 1837, and died in 1850. He was a Fellow of the Royal Society. The business was then carried on by his son Charles Frodsham, from whom the present firm name is derived and who died in 1871. H. M. Frodsham, a son of Charles, is still active in the firm.

The chief centers in England where watches are made in quantity by factory methods are Birmingham, Liverpool, and Coventry. Perhaps London and Manchester should also be mentioned.

As one (1921) walks down the streets of London and looks at the watches exposed for sale in the jewelry stores (one would say *shops* in London), one is struck by the fact that nearly half appear to be Swiss made and cheap watches. Some are English factory made. Some carry the name of the shop on the dial. A great many have trade names on the dials. Some are not marked at all. But very few American watches are seen and these are nearly all Ingersoll watches.

The French watchmakers were fine mechanics and accomplished workmen. One would thus expect in connection with their watches delicate workmanship and beautiful decoration. And this was true up to 1800 while watches were being made individually. Museum specimens are collected on account of intricate mechansim or beautiful decoration and fully half of the examples, if not more, are of French origin. Since factory methods have come to the fore, France has not (speaking relatively) made a large number of watches. But very few come to America.

One of the best known modern makers of fine watches is L. Leroy & Cie., 7 Boulevard de la Madeleine, Paris. This firm is perhaps more famous for its chronometers and precision clocks than for watches. The French navy has taken up to a recent date (before the war) perhaps 1000 Leroy chronometers and the firm has been classed first in the tests

some fifty times. A complicated watch by them was described on page 257, and Fig. 225 shows a precision clock by this firm. The history of the firm commences with Charles Leroy, who founded his establishment in the Palais-Royal in 1785 and continued there until 1804. From 1804 to 1828 it was Leroy Fils and from 1828 to 1889 Leroy et Fils. The firm name is now Leroy et Cie. and Louis Leroy and Léon Leroy are the two directors. In 1899 the business was moved to 7 Boulevard de la Madeleine and before this time a manufactory had been established at Besançon. Their timekeepers are manufactured both in Paris and Besançon, and nearly 15,000 timekeepers have been made to date.

The center of the watchmaking industry in France by factory methods is at Besançon in the eastern part of the country, near the Swiss frontier. Before the war the statement was usually made that there were some twenty or more watch firms at Besançon, that from 8000 to 15,000 people were directly or indirectly employed in watchmaking, and that about 1,000,000 watches were made annually. The war, of course, paralyzed the industry, particularly as the battle lines were not so far from the city.

Watches are tested at the "Observatoire National" of the "Université de Besançon" and an interesting and valuable "Bulletin chronométrique" is issued each year by the director, M. A. Lebeuf. In the table on page 487 may be seen the firms which usually stand at the top in the watch testing at Besançon. Leroy et Cie. and Lipmann Frères are the two best known firms in America.

Swiss watchmakers. — About three-quarters of the watches imported into the United States come from Switzerland. They are for the most part of two distinct grades. On the one hand there are the very high grade watches, expensive, and some of them intricate. The others are fair to poor and usually sold under trade names. There is comparatively little between. A Swiss watch is usually extremely good or fair to poor. Some one has said that the Swiss make the best and the poorest watches in the world.

There are two chief centers of watchmaking in Switzerland. These are Geneva and Neuchâtel, with the near-by places La Chaux-de-Fonds, Le Locle, St.-Imier, and Bienne. These last five places are all within some thirty miles of each other.

Watchmaking is said to have been introduced at Geneva by Charles Cusin, who came from Autun in France in 1574. Thirteen years later he became a citizen and was soon active in founding a watchmakers' guild. He seems to have been an energetic leader as well as a skilled watchmaker. He died in 1618. Most, however, consider the introduction of watchmaking by one man, namely, Charles Cusin, as a myth. By 1500 the famous fairs at Geneva had ended and the city was ceasing to be important. Geneva accepted the reformation and many religious refugees flocked there, bringing the trade of watchmaking with them. Cusin may have been one of them, but some would have it that he came not through religious motives but because he had stolen a horse and watch. By 1700 Geneva had one hundred masters and three hundred journeymen, and was making 5000 watches a year. By 1800 the city contained six thousand watchmakers and was producing 50,000 watches a year.

In 1680, so the story goes, watchmaking was introduced in the Neuchâtel region by a horse-dealer from the village of La Sagne, who brought with him an English watch. It stopped in the course of time and was intrusted to a skillful locksmith, Daniel Jean Richard, for repairs. He not only repaired the watch but learned how to make it and taught others. Shortly the Neuchâtel district was producing more watches than Geneva, but they were probably not as good. In 1818 this district was producing 130,000 watches a year.

By 1840 the Swiss were passing the English in the manufacture and sale of watches. The American industry had not yet been born. By 1870 Switzerland was recognized as the home of watchmaking. The English were falling far behind and the American industry was just getting under way. In 1890 Switzerland was exporting about 5,000,000 watches yearly; in 1900, 7,000,000; and in 1910, 10,000,000.

The following table gives roughly the number of watches and finished movements exported during the last six years:

1914	10 millions	1917	17 millions
1915	14 millions	1918	15 millions
1916	18 millions	1919	17 millions

The following table gives the details for the single year 1919:

Finished movements	3,388,516
Cases	886,788
Watches (metal cases)	7,196,315
Watches (silver cases)	2,864,678
Watches (gold cases)	380,316
Complicated watches	59,716
Others (including bracelets)	2,975,591
	17,751,920

Among the best known and more important makers of high grade watches may be mentioned (alphabetical order):

Paul Ditisheim of La Chaux-de-Fonds.
Jules Jürgensen of Le Locle.
Longines of St.-Imier.
Nardin of Le Locle.
Patek, Philippe & Cie. of Geneva.
Vacheron & Constantin of Geneva.

The Société Anonyme Paul Ditisheim is located at La Chaux-de-Fonds and was founded in 1892. This is one of the great centers in Switzerland of the watch industry. Paul Ditisheim not only makes watches but chronometers and deck watches as well. His output of watches is remarkably varied. It consists of intricate watches with all possible attachments, watches of all sizes from extremely small to the usual gentleman's size, and dress watches of various shapes. The cases are ornamented in many different ways. An extremely small watch, in fact the smallest in the world, was made by Ditisheim for the Paris Exposition of 1900. It is 6.75 millimeters (3 lines) in diameter and the whole movement weighs less than 95 centigrams (0.95 grams). It is here illustrated in natural size (Fig. 293). This watch is

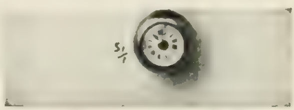
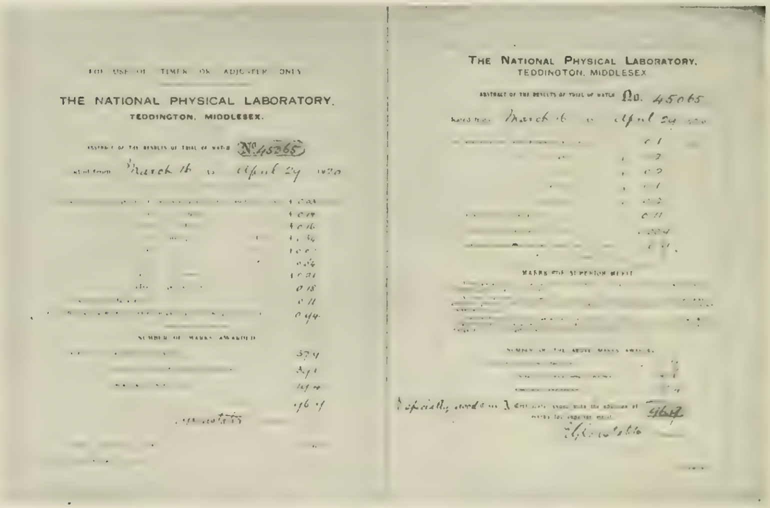


FIG. 293. — AN EXTREMELY SMALL WATCH, BY PAUL DITISHEIM.

now owned by the Sultan of Morocco. He has also made some of the most complicated watches ever constructed. One of these was described on page 257. His watches are also noted for their accuracy. In fact he may safely claim to hold the world's record for accuracy.

In England watches could formerly be submitted to the Kew Observatory at Richmond, Surrey, for tests. This service was established in 1884 and in 1912 this rating work was transferred to the National Physical Laboratory at Tedding-

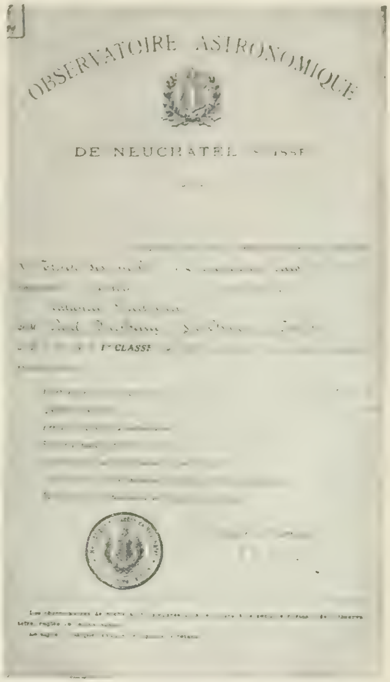

THE NATIONAL PHYSICAL LABORATORY.
TEDDINGTON, MIDDLESEX.
No. 45065

THE NATIONAL PHYSICAL LABORATORY.
TEDDINGTON, MIDDLESEX.
No. 45065

FIG. 294. — A TEDDINGTON CERTIFICATE FOR WATCH, DITISHEIM NO. 45065.

ton, near London. During the twenty-nine years, 15,301 timekeepers were submitted for tests at Kew. The three best of all these were made by Ditisheim. The record is held by No. 36175, which in 1912 secured 96.1 points out of a possible total of 100. The second place at Kew is held by Ditisheim's No. 16639, with 94.9 points, and the third place by his No. 34122, with 94.8 points. At Teddington the record to date (1920) is held by Ditisheim's No. 45,065, with 96.9 points. Its certificate is here reproduced as Fig. 294. In Neuchâtel watch testing was commenced in 1876. The

record to date (1920) is held by Ditisheim's No. 36145, with 40.6 points. A copy of its certificate is also given as Fig. 295. The many improvements which he has recently introduced in the chronometer have been noted and illustrated on page 275. Mr. Ditisheim is not only engaged in the business of making accurate timekeepers but is also deeply interested in all research in connection with them and is the author of many research articles.


OBSERVATOIRE ASTRONOMIQUE

DE NEUCHATEL

1re CLASSE

FIG. 295. — A NEUCHÂTEL CERTIFICATE FOR WATCH, DITISHEIM NO. 36145.

The watchmaking firm of Jules Jürgensen was formerly located at Le Locle. There have been several generations of famous watchmakers. The firm was first established by Urban Jürgensen at Copenhagen, Denmark, in 1740. His son Urban was born in 1776 and died in 1830. He was an eminent Danish watchmaker. His two sons were Lewis and Jules. Jules Jürgensen in 1835 established a branch at Le Locle and became one of the most noted watchmakers of the century. He had been born at Le Locle July 27, 1808, during a temporary sojourn of his parents. He directed the business until his death in 1877 when it was taken over by his two sons Jules and Alfred. Jules directed the house until his death in 1894. Very recently (1919) the business has been taken over by a firm at Bienne and the Jürgensen watch is now manufactured there. A portrait of Jules

Jürgensen, who founded the firm at Le Locle, is shown in Fig. 296.

The magnificent Fabrique des Longines is located at St.-Imier. The business was founded in 1866 and the factory has been enlarged from time to time until at present nearly 2000 persons are employed. The present appearance of the factory is shown in Fig. 297. All grades of watches are made, including precision watches, which take first place at the observatory tests. The current numbers which are now (1920) used on their watches are between 2,900,000 and 3,000,000.

FIG. 296. — JULES JURGENSEN, 1808-1877.

The house of Nardin at Le Locle dates back to Léonard Nardin, who was born in 1792 and apprenticed to his uncle. His famous son, Ulysse Nardin, was born at Le Locle in 1823. His son Paul-David Nardin was born in 1855, took up his father's business in 1876, and died in 1920. The firm specializes in marine chronometers, for which it is world famous, but it makes precision watches as well.

The present firm, Patek, Philippe & Cie., at Geneva, was founded by A. N. de Patek, a Polish gentleman, in 1839. It really dates from 1845, when Adrien Philippe, a talented French watchmaker, joined de Patek as partner. De Patek was the business manager and Philippe the skilled watchmaker. It was Adrien Philippe who in 1844 invented the stem winding and stem setting watch and for this he was awarded a medal at the Paris Exposition of 1844. From time to time the factory was enlarged and finally it was taken down and entirely rebuilt in 1891. It is located at the southern end of the Mont Blanc bridge facing the lake.

The firm makes precision watches of all sizes and with cases decorated in many ways. During the last eight years (1913–1920) watches made by Patek, Philippe & Cie. have stood first five times in the watch tests at the Geneva Observatory. The company also constructs complicated watches and one of these was described and pictured on page 259. The two founders of the firm are pictured in Fig. 298.

The firm Vacheron & Constantin was founded in 1785 and is thus the oldest Swiss watch factory. The Vacheron

FIG. 297. — THE LONGINES WATCH FACTORY AT ST.-IMIER.

family is no longer connected with the firm, but the Constantin family still retains its connection, two of the five directors at present being of that name. A picture of the early factory just after 1800 is shown in Fig. 299. In 1875 the new factory was put up. In 1838 this firm introduced the principle of interchangeability in the construction of watches. This means that the watch parts were made by machinery, so that each part of every watch of the same model would be exactly alike and thus interchangeable. This firm manufactures all parts of a watch movement in its own factory and thus differs from most firms which buy

many parts and thus only assemble the watch. They make precision watches in many sizes with cases decorated in many ways and complicated watches as well. One of these was described and pictured on page 259.

There are two Swiss firms which make all grades of watches in large numbers, including precision watches as well. These are S. A. Louis Brandt, Montres Oméga at Bienne, makers of the Omega watch, and Fabrique de

FIG. 298. — A. N. DE PATEK AND ADRIEN PHILIPPE.

Montres Zénith at Le Locle, makers of the Zenith watch. The current numbers (1920) used by the Omega firm are a little over 4,000,000 and the numbers used by the Zenith firm, about 2,000,000. These numbers must not be taken to indicate exactly how many watches have been made by each firm. The numbers used by watchmaking firms do not always start at one and sometimes devices are used to cover up the exact output. Usually, however, the numbers indicate roughly how many timepieces have been made. For example, the Omega firm in an advertisement (Novem-

ber, 1920) states that 6,000,000 Omega watches have been made to date.

The current (1920) numbers used by Paul Ditisheim at La Chaux-de-Fonds are roughly 37,000; by Patek, Philippe & Cie. at Geneva, 178,000; and by Vacheron & Constantin at Geneva, 384,000.

German watchmaking. — German watches and watchmakers are practically unknown in America. The best known firm is perhaps that of Lange & Söhne in Glashütte. Adolf Ferdinand Lange, the founder of the firm, was born in Dresden in 1815. He was early apprenticed to a watchmaker of that place. Later he went to Paris and there became foreman in the workshop of the famous Winnerl, maker of precision clocks and chronometers. He returned to Dresden and in 1845, with the help of the state, established a school for watchmakers at Glashütte. The first watches were put out in about two years. The enterprise grew until Glashütte is now one of the centers of watchmaking in Germany. He died December 5, 1875, famous as a maker of fine watches, chronometers, and precision clocks. His two sons, Richard and Emile, continued the business.

FIG. 299. — THE WATCH FACTORY OF VACHERON & CONSTANTIN AT THE BEGINNING OF THE NINETEENTH CENTURY.

CHAPTER XXIII

THE CARE, REPAIR, AND ACCURACY OF CLOCKS

As regards care, repair, and accuracy timekeepers may be divided into three classes, — chronometers, clocks, and watches. Chronometers have been sufficiently considered in Chapter XVI on "The History, Construction, Care, and Accuracy of Chronometers." Watches will be taken up in the next chapter. This chapter is devoted to the consideration of clocks.

At the very outset it will be necessary and should be interesting to classify the various kinds of clocks which are met with at the present time. There are (1) tower clocks. These should perhaps be subdivided into two groups, old and modern. Those constructed during the last sixty or seventy years may be considered modern. Those older than that are fast wearing out and can hardly keep up to the modern requirements of accuracy. The care bestowed upon them should be the same in kind and greater in amount than that given to a modern tower clock. There are (2) electric clocks. A clock in which electricity is used in any form is here considered an electric clock. It may be used to wind up the clock at stated intervals. It may be used to synchronize the clock with some master clock occasionally. It may be used to drive a controlled clock in unison with a master clock. It may play an important part in the mechanism of the clock itself. There are (3) precision clocks. Regulators and astronomical regulators are included under this head. There are (4) domestic clocks. This term covers many kinds and varieties. A modern clock factory makes at least forty or fifty different kinds of movements and cases them in several hundred different kinds of cases. This head includes all clocks from the

ponderous grandfather to the smallest nickel alarm clock. Domestic clocks may be subdivided into two groups: antique clocks and modern clocks. Modern clocks can be said to date from about 1860. Any clock older than that can be classed among the antiques. If this classification were to be carried out in detail, each of the two groups would be subdivided into many different kinds. There are (5) intricate timekeepers or timekeeping marvels. These are usually found in cathedrals, public buildings, or museums. Some modern ones have been constructed for expositions. Most of them are clocks of large size, although some have taken even the form of watches.

Three previous chapters have taken up in detail tower clocks, electric clocks, and precision clocks, so that nothing more need be added here as regards their care, repair, and accuracy. These matters have all been covered with sufficient fullness.

Timekeeping marvels will not be given further consideration here. There are very few of them, and many of them are not kept running. They of course require expert attention if any repairs are necessary. Their accuracy is always much inferior to that of simpler clocks.

Of the antique clocks only one kind will be considered and that is the Yankee shelf clock. What is said about it will in a certain sense apply to all. Antique clocks are to be found in large numbers in museums and private collections, but they are also widely scattered in private possession. There are many families which are happy possessors of one or more of these treasures. Those of American make include grandfather clocks, wag-on-the-walls, shelf clocks, banjo clocks, and a very few of more unusual forms. The others in this country are of English, Dutch, French, and German origin and in number the countries stand in about the order given. The shelf clock was chosen because it is still obtainable in fair supply and at a moderate price. An amateur can afford to try renovation on one of these. The others are too valuable for such experiments. The accuracy of these old clocks is often remarkable. They

frequently run as well as a modern clock, costing what they did when they were new.

This chapter, then, will really consist of two parts. In the first, the modern domestic clock will be considered. The second part will be devoted to the renovation, care, and accuracy of the old American shelf clock. This has been introduced largely on account of the interest which amateurs and collectors have in this subject.

The classification of clocks which has been given is, of course, not the only possible one. They might have been classified by the place or position which they usually occupy. There would thus be tower clocks, table clocks, bracket clocks, mantel clocks, shelf clocks, pedestal clocks, wall clocks, and the like. The attempt has also been made to keep certain of these terms for some particular antique clock, but there is no uniformity in the use of terms.

Clocks may also be classified in accordance with the most unusual and peculiar thing about them. Thus we have musical clocks, chiming clocks, alarm clocks, calendar clocks, equation of time clocks, repeating clocks, and the like.

I. Modern Domestic Clocks

This term is here used for the many kinds and varieties of clocks which are in common use in the home. In size they vary from the largest grandfather clock down to the smallest nickel alarm clock. In price they vary from nearly \$1000 for a fine grandfather clock in a superb case with chimes and many attachments down to 59 cents (marked down from 65 cents) for the cheapest alarm clock. Most of them are "made in America," although there are many of English, French, Swiss, and German origin. The number of varieties is almost endless. As has already been said, a large modern clock factory will make perhaps fifty different kinds of movements and case them in several hundred different kinds of cases. It is thus impossible to treat in detail every kind of modern domestic clock. It will be necessary to treat them in general terms as a class.

They naturally differ considerably in construction. They are both weight-driven and spring-driven. In number the spring-driven clocks are far ahead. Small clocks are all spring-driven. Some larger clocks and all grandfather clocks are weight-driven. The weight has the decided advantage that the driving power on the movement is always the same. The use of a fusee in connection with a spring is very rare. Its use is confined mostly to English-made clocks. Many good clocks have stop work in connection with the spring so that only a fairly uniform middle portion is used. Clocks are either pendulum controlled or balance controlled. Practically every weight-driven clock is pendulum controlled. Spring-driven clocks may have either a pendulum or balance. The pendulum usually consists of a metal rod and a heavy, lens-shaped lead bob, although this is the worst possible form. The effect of temperature changes is then the greatest. A wood rod and large zinc bob, supported from the bottom, are far better. This is found in most grandfather and long clocks. Many clocks have mercury compensation pendulums. A word of caution is needed here. All is not mercury that appears to be. There are many imitation mercury pendulums. The gridiron and alloy pendulums are very seldom used. The length varies from the length of the seconds pendulum as found in the grandfather clock to lengths of only three or four inches in very small clocks. The escapement used with a pendulum is either a dead-beat anchor, a recoil anchor, or a Denison gravity escapement. The last is very seldom used and only on large clocks, such as regulators. The dead-beat anchor is occasionally used in very high-grade movements. Some form of the recoil anchor is the common form. Sometimes the dial is cut away so as to show the escapement. Sometimes it is placed in front of the dial. When a clock is controlled by a balance, the escapement is either the cylinder or detached lever. The duplex has been used, but has practically disappeared at present. All nickel alarm clocks have a detached lever escapement. A cylinder escape-

ment is nearly always found in what is termed in America, "a French traveling clock." These clocks are from two to six or seven inches high and have a brass case with glass sides. There is often an outer protective case of leather or imitation leather. The movement is visible and is particularly well made and finished. In Europe these are termed carriage clocks because they can be so easily carried about. All clocks are very much alike as regards the transmitting and indicating mechanism. Far more than half the clocks (excluding nickel alarm clocks) are striking clocks. If American made, the count wheel is ordinarily used. English and French clocks are more likely to make use of the rack and snail. Grandfather clocks and many fairly large clocks are likely to have chiming, musical, calendar, equation of time, and moon phase attachments. There are naturally a very few clocks which are decidedly different from the general run of domestic clocks. Two of these will be mentioned in passing. These are the four hundred day anniversary clocks, with a rotating pendulum, and the clocks which swing like a pendulum.

Care. — In caring for an ordinary domestic clock there are several matters which need attention. More is probably expected of a clock and yet it gets less care and attention than any other piece of machinery.

In the first place, temperature changes should be avoided as far as possible if the clock is expected to do its best. This means that a clock should not be placed over a stove in which there is a hot fire one day and none the next. It means that the sun should not be allowed to shine directly on a clock. It means that it should not be placed over a radiator in which there is heat part of the time and none at others. It does not mean that constant care must be used to keep the temperature of the room constant. A clock must be used without thought but not abused.

It should also be wound regularly. The morning is the best time for a one-day clock, as one's habits of life are more regular in the morning than at night. It should not be wound too tight. It is preferable to know the number of

half-turns necessary for winding so that the last two may be made carefully and slowly.

There is a widespread popular notion that a pendulum clock will not run well if the case is not level. The idea back of this is correct. The case does not need to be level, but the movement should be so placed that the pendulum swings equal amounts each side of the position of rest in allowing a tooth of the escape wheel to escape. If this is correct, the clock is said to be in beat. It may be roughly judged by noting if the interval of time between successive ticks is the same. It is easy to detect a large discrepancy, but it is not so easy to be sure of a small difference. Most clocks are not very sensitive, so that if no difference can be easily noticed the clock can be assumed to be near enough in beat. There is a better way if the pendulum is accessible. Stop the pendulum, and when it is at rest so place the eye that it is in line with some well-defined part of the case or movement directly back of it. Then with the hand slowly move the pendulum to the right and left until a tooth of the escape wheel passes. The eye can readily judge if the amount of motion necessary is the same on both sides of the position of rest. Sometimes it would be necessary to put the clock case too much out of level to look well to put the pendulum in beat. To avoid doing this, sometimes the movement can be twisted a little in its case. If not, the crutch which connects the anchor and pendulum can be bent. Any one who knows something of clock mechanism can do this. No tools are necessary. The small wire can be easily bent with the fingers. One who tries it for the first time will be surprised to find how little bending accomplishes large results. The crutch is not always easily accessible. Often the hands and dial must be removed to get at it. Sometimes the crutch is fastened to the pendulum by adjusting screws for the express purpose of making this adjustment easy. This is true of many clocks with fairly large pendulums.

A clock may be set backward as well as forward. If it is a striking clock or has attachments it should be set back

only a few minutes. Some think that a clock should not be set back just after it has struck the hour. This is a mistaken idea. The clock will not strike the hour again. It should be set back of course only a very few minutes, say two or three. A firm support for a clock not only makes for safety but also causes it to run better. Dirt and dust should also be avoided. This will not affect the rate particularly, but it will make necessary the cleaning and oiling of the clock much more often.

Cleaning. — With time all clocks become dirty and the oil thickens and becomes gummy until they finally stop. Before a clock absolutely refuses to run, there are usually certain preliminary symptoms. It stops if the room gets unusually cold. When it warms up again, it will go. It often has a series of faint ticks and then they grow louder as if the power had been nearly off and had come on again. Most people allow a clock to run until it is actually stopped. This can hardly be recommended as an ideal treatment for clocks, yet they do not seem to be really injured by it. It would probably be better to take a clock to a jeweler every five or six years for cleaning and oiling, even if no part had broken and there was no need of repairs. If pivots actually become dry, there is danger of cutting and wearing them and of enlarging the pivot holes. Jewelers and clockmakers will say that a clock should be cleaned and oiled every two or three years. They are probably over-careful and perhaps looking out for their own interests. It is probably eight or ten years before the average clock gets cleaned and oiled if nothing happens to it. This is entirely too long, however.

If a good clock is taken to an honest and skillful jeweler for cleaning and oiling, what he does is something like this. In the first place, the movement is removed from the case. Clock movements are fastened in their cases in different ways, so that no specific directions can be given. It is always easy, however, to take out a movement. Sometimes it comes out of the back and sometimes the front of a clock. Sometimes parts of the movement, such as hands,

dial, or pendulum, must be removed first. Often on removing a few screws the movement pulls out as a whole. The hands, dial, and pendulum, if it has one, are now removed, if this has not already been done. The movement is next carefully looked over to see if every part is right and if there is need of any repairs. The points to note in particular are that all wheels are free, that the depthings are correct, that the pinions are free from rust, that the pivot holes are not unduly worn, that the pallets are not pitted, and that the teeth, particularly of the escape wheel, are not bent. Here is where the honesty of the jeweler comes into play. He should not hunt for trivial or imaginary faults, so that he can use them as talking points and thus charge the customer more than the usual amount. On the other hand, he should not pass over a serious defect which in a short time would surely bring the clock back again for repairs or slight faults which can be remedied in a moment. An example will suffice. All pivot holes wear in time. They become elongated and too large and either cause the clock to run badly or stop. Such a pivot hole should be bushed or made small in some way. This is necessary work and for the best interests of the customer. The jeweler, however, should not find three or four holes that are just a little worn, do a little something with them, taking a few moments of time and then charge a large amount for his time in "making extensive repairs to a clock movement which was in very bad shape." If a clock movement is at all unusual or has complicated attachments, a jeweler will notice carefully, as he looks it over, just how it goes together. Perhaps he will even mark certain parts so as to be sure to get the movement together right. The springs are now let down if it is a spring-driven clock. If weight-driven, the weights had to be removed before the clock movement was taken out of the case. The plates are now separated and the movement taken entirely to pieces.

Now comes the cleaning. All pivot holes are cleaned by inserting peg wood in each one. Peg wood consists of small round sticks of wood, often dog-wood or orange-wood.

These sticks can be purchased. In using it, a stick is shaped to a point and the point inserted in the pivot holes. As it becomes soiled the point is cut away and a new point made. This cleaning should be continued until the point shows no soil when inserted in a pivot hole. The plates and parts are cleaned by brushing them with a suitable jeweler's brush which is rubbed from time to time on prepared chalk. If any part is particularly dirty or gummy it may be put in gasoline and wiped on a piece of soft cloth or tissue paper. Polished brass plates, if tarnished, are cleaned by a jeweler by using a cyanide of potassium bath. After every part has been cleaned, the movement is put together again and oiled. The repairs have of course been made before cleaning, if any were necessary. It is then put in a movement holder and allowed to run. Here it is timed to run fairly closely and looked over to see that everything is all right. The case is dusted out and perhaps a little time is spent in renovating it. This would depend upon the directions left by the customer. The movement is now put back in the case and the task is completed.

Cheap clock movements are not usually taken apart for cleaning. If they are, the charge would necessarily be about as large as the cost of the clock. The "gasoline pail in the back room" is used for these. The movement is taken out of the case and the hands and dial are removed. Then the whole movement is put in a vessel of gasoline. It is sometimes allowed to run in the gasoline. If balance-controlled, the balance and lever are usually removed, so that it will run down rapidly. This really dissolves the dirt and old oil well, but it does not leave the movement in good condition for the preservation of the oil. The movement is now taken out of the gasoline, wiped a little, and allowed to dry. It is then oiled and put back in its case. This is not an ideal treatment but, frankly, a jeweler cannot do any more without charging as much as a new clock is worth.

When an ordinary clock stops, many frugal and industrious housewives immediately get the "feather and kerosene can." This feather is dipped in kerosene, pushed

into the clock movement, and then moved around indiscriminately. Then often the clock will run again. Enough kerosene has reached the parts to dissolve the dirt and gummy oil and supply a little lubricant for a further run. It is naturally not a treatment to be recommended, particularly for a good clock A further difficulty is that the oil gets on the dial and spots it. The amateur who knows a little about clock mechanism can do much better than this. The thing to do is to remove the movement from the case and take off the hands and dial. Then apply a couple of drops of gasoline to each pivot by means of a small camel hair brush or a tooth pick (the amateur's peg wood).[1] Allow the clock to run and then wipe off all the dissolved dirt and old oil from the pivot holes. If very dirty, gasoline may be applied several times. Finally apply good oil and let the clock run some. Again wipe the arbors and pivot holes. Perhaps just a little more oil should be added to each pivot before putting the movement back in the case. The oil can be readily applied by means of an orange-wood tooth pick or a piece of fine wire. An ordinary clean steel pen in its holder is also good. Good oil should be used and the quantity should be small. Two drops are more than enough for a clock. The amateur always uses too much. More will be said later in connection with oiling watches about the kind of oil to be used.

Repair. — If something breaks in connection with a clock or it is in need of repairs, it should be taken to a good jeweler. Some one has said that an amateur should only experiment with an old alarm clock costing less than one dollar or a clock purchased at an auction for less than two dollars. It is good advice. As the amateur gets out of the beginner's class or the apprentice gains skill, better clocks may be taken in hand.

No definite directions for repairing can be given, for it, of course, all depends upon what has broken or is in need of repairs. To take up all the different things which might

[1] An amateur must not forget that gasoline is inflammable and use it in a dangerous way.

happen would be to write a practical manual for the clock repair man. There are many such manuals, and they are listed in Appendix V.

Accuracy. — Modern domestic clocks are of so many different grades and the quality of the movements is so very different that no definite figures for the accuracy can be given. A grandfather clock, which has cost more than $150, or any other clock which has cost more than $15, ought to keep time within less than a minute a week. Sometimes they will do better for short periods.

II. The American Shelf Clock

This portion of the present chapter deals with the renovation of the antique shelf clock It will be of primary importance to those who deal in antiques or collect antique clocks; it will be interesting to any one who is the happy possessor of such a clock; it can also be recommended to all those who like to use tools and finish wood work, for there is no pastime more fascinating than the renovation of an old clock. The American shelf clock has been chosen because, in the northeastern portion of the United States at any rate, it is still in fair supply at a moderate price. The other forms of American-made antique clocks, such as the grandfather, the wag-on-the-wall, and the banjo are too scarce, too closely held, and too valuable for amateur experiments. If they are in need of repairs or renovation they should be entrusted to an expert. A clock a hundred years old, if ruined, cannot be replaced. And, furthermore, what is said about the shelf clock will apply in large measure to all antique clocks.

In purchasing an old shelf clock which has not been renovated there are four things to notice: (1) if the clock-paper is still in the clock; (2) if the painted glass panel in the door has been broken or replaced; (3) if the veneer on the case has been burned or badly broken off; (4) if the movement has been badly broken or damaged. It is to be expected that the case has received several coats of var-

nish, Jap-a-lac, or even paint; that it shows the effect of smoke and dirt; and that the veneer has chipped off in small places. As far as the movement is concerned, it is to be expected that it is too gummy and dirty to run; that the weight cords have broken; that the pendulum spring is perhaps broken; that the rods in the striking mechanism are perhaps bent; that a hand is perhaps missing; and that a few teeth may be bent. If it has wooden works it may be that some of the wooden teeth have been broken off. A clock with clock-paper and original painted panel in the condition just described is worth from $5 to $15. The price will depend upon the kind of clock, where purchased, and other circumstances. If there is no clock-paper, if the painted panel has been broken or replaced, if the case is in bad shape, and the movement badly damaged, then the clock is not worth more than from $2 to $5.

Practically all dealers in antiques will have one or two of these clocks which have been renovated and put in running order and are on sale. They will probably have in a back room many more which have not been renovated and are of course for sale. They can often be purchased at auctions, and there are many reposing in attics and woodsheds which may be had for the asking if one is a relative or friend. The supply is of course limited, for it cannot be added to and the demand is increasing. Nevertheless, in New England at any rate, there is no difficulty in getting antique shelf clocks either renovated or unrenovated. The author has in mind at present at least three dealers in antiques in small towns or villages each of whom has for sale from five to fifteen of these clocks.

Let us suppose that an old shelf clock has been purchased and that it is in fair condition for an unrenovated clock. The first thing to do is to take off the door, as that must be renovated separately and it might get broken. Next take out the movement. To do this unhook the weights first, then remove the hands and dial, and finally the pendulum and verge. The movement can now be pulled forward out of the case. There are now three parts

to be taken in hand — case, door, and movement. The material of which the case is composed is in most instances mahogany veneer. The pillars and certain panels may be solid — perhaps mahogany, more likely some hard wood, mahogany finished. Sometimes the pillars and the scroll at the top have been decorated with gilt and stained black. An inlay is very rare indeed. If there is inlay and the pieces are loose, or if pieces of the mahogany veneer have cracked loose, the first thing to do is to glue them fast. Some good glue should be used. It must be worked well under the piece, which should then be clamped down hard. A piece of oiled paper should be put over the veneer, and a smooth board over this before applying the clamp. If the surface is curved, then a piece of board, having the same curve, must be used for holding the veneer in place. This should be given at least a day to dry before anything else is done.

The next step is to remove the old varnish and paint; in fact, everything right down to the wood. It may be scraped off by means of a piece of glass, an old knife, or a metal scraper. Glass is not good, as it is too apt to break and cut the hand. Care must be used in scraping. One must scrape with the grain of the wood — never against it or across it. The scraper should be held at an angle of about 45° or a little more. Even, steady strokes are the best.

A varnish remover is more often used. To do it in any other way requires too much time and patience. The ordinary varnish removers which can be purchased at any paint store are generally employed. The advertisement usually states that it will not injure the wood, that it will not hurt the hands, that it evaporates slowly, and that the odor is not unpleasant. If these statements were all true, it would be an ideal product. Some, however, hesitate to use an ordinary varnish remover on a very expensive old clock case. A varnish remover which is surely harmless may be made from equal parts of wood alcohol and benzole. A little paraffin may be added to keep it from evaporating too quickly. The paraffin is put in the benzole and the

wood alcohol is then added. After the varnish remover has been applied and the varnish softened it may be removed with a putty knife or an ordinary pocket knife with a large blade. This will take off most of the paint or varnish, but there will still be spots and streaks and the moldings and corners will need special attention. The case may be "cleaned up" by using more varnish remover on these obstinate places or by using wood alcohol. If the clock case has black and gilt pillars or scroll it is better not to use varnish remover on these, but simply to rub them, as will be explained later. Some advocate using strong ammonia to soften the varnish instead of a varnish remover. The danger is that, if left on too long, the wood may be darkened. If this has happened it may be bleached by means of a solution of oxalic acid in water. About two tablespoonfuls of the acid crystals should be added to a pint of boiling water to make the solution. Care must be used not to bleach too much.

The next step is to repair the case and patch the veneer. In making repairs to the case use glue mostly. Beware of using nails. A few hints about patching veneer may be of value, although this is largely a matter of practice. Some pieces of old veneer can probably be obtained from the dealer in antiques in your town or from the furniture man or from any one who makes picture frames. Sometimes it is necessary to soak it in order to get the veneer off of the old piece of wood. Usually it can be split off readily. It must be thoroughly dried again before being used. Next shape the hole to be covered by the patch. Cut along the grain of the veneer as far as possible. Never cut at right angles to it. When necessary to cross the grain do it at an angle. Never use a square or rectangular patch unless it extends across the entire side. The reason for all this is to make the patch as invisible as possible. Next choose a piece of veneer of the same color and texture as the case and cut a patch the same size and shape as the hole. Use plenty of glue, clamp it in position, and leave it at least a day to dry.

Sometimes the veneer is patched by inlaying a piece of wood, usually natural mahogany. This is more often done if the damaged veneer comes near the middle of one side of the case. Then a diamond-shaped piece is cut out and the inlay is put in. This is usually left an eighth or a quarter of an inch higher than the surface of the veneer. This method of patching of course requires a similar inlay on the other side of the case on account of symmetry, even if there is no damage to the veneer there. This often looks quite well, but the objection is that the shelf clock never had any inlay work of any kind. Its presence therefore brands the clock as having been renovated in a modern way.

We will now assume that the case has been repaired, that the veneer has been patched, and that the glue is dry. The case must next be rubbed down. The purpose of this is to remove the last traces of varnish or paint, to make the wood perfectly smooth, and to make the patches blend with the case. Sandpaper or emery paper, which may be purchased at any paint store, are good to start with. The finishing should be done with pumice stone and olive oil. In place of olive oil any rubbing oil or even water can be used. Do not get weary with well doing and neglect the rubbing. It is the secret of a fine finish so *rub*, RUB, RUB, until everything is clean and smooth. In connection with black and gilt pillars and scrolls it is better not to use varnish remover but simply to rub them with pumice and oil until they are clean and smooth. Do not rub enough to take off the gilt or black. If the black is off in places, a wood dye may be used to color the spots. Do not retouch the gilt unless very necessary. It is impossible to make the new look old like the rest. The case should now be wiped perfectly clean; it is then ready for the final operation.

Sometimes it is necessary to use material of a different color in repairing a clock case or in patching the veneer. It is then necessary to stain or overshade this to bring everything to the same color. A suitable wood dye or powdered stain soluble in oil, alcohol, or water is ordinarily used, and any one visiting a shop where antiques are being renovated

will be struck by the facility with which any kind of wood — mahogany, walnut, cherry, even pine — is made to resemble nice dark red mahogany. Burnt sienna in turpentine is a simpler overshade to use. The resulting color tone is quite red. If a wood dye or stain has been applied, it is necessary to allow it to dry thoroughly and then to wipe off the case before finishing it.

These clock cases are either varnished, or varnished and then rubbed to get a duller finish, or oiled, or oiled and waxed. If the case is to be varnished, then, when clean and dry, this should be done with furniture, or coach, or rubbing varnish. At the paint store many different kinds of varnishes may be purchased. A high grade varnish, which can be rubbed, should be procured. It may be called a furniture varnish, or a coach varnish, or a rubbing varnish. A thin, even coat should be put on. Be sure that the brush is clean and free from oil, or little lumps will result. When this is thoroughly dry a second coat may be given and then a third. Some prefer shellac rather than varnish. If one does not like a gloss finish, it may be dulled by rubbing with pumice and olive oil. Care should be taken not to rub the corners and edges too much. Of course the varnish should not be rubbed until worn thin. The right amount of rubbing necessary to get the required finish can only be learned by practice.

If an oil finish is desired, then the case is rubbed with a soft woolen cloth moistened with olive oil. The oil is improved for this purpose if a few drops of a strong solution of camphor gum have been added. Finally the excess oil is wiped off with a soft cloth and the case is finished.

If the case is to have a wax finish, then the wax is applied after the oil. There is an old English saying: "Feed your wood with oil and polish it with wax." Suitable wax may be purchased at any paint store. Apply a little wax at a time and then rub it in briskly. The rubbed varnish or the wax finish are probably the two most desired at present.

Sometimes a case is in such condition that it seems un-

necessary to take off the old varnish. It can be very much improved by rubbing it lightly with pumice and olive oil to remove the surface dirt and smooth it a little. It may then be varnished, or varnished and rubbed, or oil finished as desired. To give it an oil finish would probably be best, as it already has a coat of varnish.

The door may now be taken in hand. The woodwork must be renovated in the same way as the woodwork of the case. Great care must be exercised not to break the painted panel, as this is a very valuable part of the clock. In fact the painted panel should probably be taken in hand before the woodwork. If the panel can be easily removed it should be taken out and put in a safe place. Occasionally an old clock has a painted panel in first-rate condition, but usually the paint has cracked and chipped off a little in places, and adheres to the glass so lightly that the slightest rub would brush it off and spoil the picture. The thing to do is to flood the picture with shellac. Hold the painted panel horizontal with the painted side up and pour on quite a little shellac. If it runs off, no matter. Tip the panel slightly to one side and then another, so that the shellac covers the whole of it. *Never* attempt to put it on with a brush, as it would spoil the painting instantly. Lay it down in a horizontal position and let it dry thoroughly. The picture is now firmly set fast. It may now be painted over the shellac with the original background color. If it is black, use either dull or gloss black paint; if white or pearly white, use the corresponding color. The painted panel in the clock pictured in Fig. 255 has been treated in this way. It was in such bad condition that it was impossible to take the door off the clock case or the panel out of the door before flooding it with shellac. It was afterwards painted a pearly white (gloss white paint colored with a little burnt sienna) over the shellac. While not perfect, it is the original picture and is so much better than any modern replacement.

In probably three quarters of the shelf clocks the painted panel has been broken. When this has happened there are four possible substitutes: (1) a modern painted panel; (2)

a bronze looking-glass effect; (3) a black and gilt conventional painting; (4) a paper on glass substitute. If one is fortunate enough to be able to paint a picture on glass, it solves the difficulty at once. In fact it may be more artistic and pleasing than the original picture. The only objection is that it is new and not the original. The clock illustrated in Fig. 243 has a modern painted panel. The second way is to take a piece of plain glass of the proper size and paint it with a dark brown gloss paint. This resembles a bronze looking-glass, and it will be remembered that many of the shelf clocks were originally provided with these bronze looking-glasses instead of painted panels. The third way is to paint some conventional black and gilt design on a piece of plain glass. Any one is enough of an artist to do this. A big gilt circle or rectangle may be placed in the middle and then the whole painted with gloss black paint. As one gains more facility and confidence, more elaborate gilt designs may be attempted. The fourth way is to fasten a paper picture on a piece of glass. By this is meant far more than to cut a picture out of a magazine, paste it on a piece of cardboard, and tack it in the clock door. This has been done from time immemorial and is usually far from artistic or pleasing. Some highly colored picture is needed. Red and black go very well together. For example, the colored picture of a robin may be taken from some publication illustrating our own birds, or a red flower from some flower seed catalogue, or a red apple from some nursery catalogue, etc. Cut it out carefully, leaving only the colored picture itself, not the background. Put it in a dish of shellac for about half an hour until the picture is thoroughly soaked in it. Take a plain piece of glass, the proper size, and coat it with shellac. Then place the picture on the glass, face side to it, and be sure there are no air bubbles between. When thoroughly dry, paint over the shellac, picture, and all with gloss black paint. The effect is very pleasing. The clock pictured in Fig. 256 has a substitute for the original painted panel of this kind.

The other part of the door, besides the woodwork and

the painted panel, which needs attention, is the key-hole. Most of the old clocks had a little diamond-shaped ivory inlay around the key-hole. In many cases this has been lost. A very pleasing inlay to take its place may be made out of thin sheet copper.

The movement itself now remains to be renovated. Here definite rules can not be given, as the needed repairs are so very different. Practically every movement is so dirty and gummy that cleaning and oiling are a necessity. The amateur is not advised to separate the plates and take the movement entirely to pieces. The best way is to follow the suggestions given on page 447. If a pivot is badly worn or a pivot hole is much enlarged or elongated, it ought to be bushed. This again is work for the experienced jeweler and not for the amateur. The striking mechanism will probably give trouble. It may not strike at all or it may not stop after it once starts. This is remedied usually by bending some of the rods just a little. The hook which drops into the slots of the count wheel is one of the first parts to be noticed carefully. Do not begin by bending the rods promiscuously. Be sure that it will help matters before doing anything. Good heavy fish line serves well for weight cords. A new pendulum rod or hands must be procured of a jeweler and the cost is small. If the movement is brass and some of the teeth are bent, they may be carefully bent back into place with a pair of pliers. If it is a wooden movement and some of the teeth are broken off, they must be replaced. This is done by cutting a small section out of the wheel and replacing it with a similar section from another wheel of the same size. This is again a very troublesome task for an amateur. If he attempts it, he will be obliged to get a piece of a wooden wheel from a jeweler. It will also be necessary to separate the plates and take the movement to pieces.

The clock has now been renovated — case, door, and movement, and it only remains to put the parts together. Put the movement in the case without weights, dial, hands, pendulum, or verge. Next put on the verge. The weight

cords are now run over the pulleys in the top of the case and the weights are attached. Wind up each a few turns. Next slip the pendulum rod through the loop in the crutch and attach the pendulum spring to the support. Put on the pendulum bob and put the pendulum in beat, bending the crutch if necessary. This should be done with the clock case level or better still, in the place which it is going to occupy permanently. The dial and hands may now be put on, and lastly the case door may be fastened in place. The clock is now a thing of beauty; its rhythmic tick-tock is music to one's ears; it is time to rejoice at the results of one's handiwork.

As regards the care of one of these shelf clocks it is interesting to quote from Chauncey Jerome. It will be remembered that he was one of the three great figures in the early history of clockmaking in America. Having made so many thousands of shelf clocks he ought to be an authority on their care. In his *History of the American Clock Business for the Past Sixty Years*, he gives these "general directions for keeping clocks in order":

Pendulum clocks are the oldest style, and are more generally introduced than any other kind. I will give a few simple suggestions essential for keeping this clock in good order as a time-keeper. In the first place, a clock must be plumb (that is level); and what I mean by plumb, is not truing up the case to a level, but it is to put the case in a position so that the beats or sounds of the wheel-teeth striking the verge are equal. It is not necessary to go by the sound, if the face is taken off so that you can see the verge. You can then notice and see whether the verge holds on to the teeth at each end the same length of time; or (in other words) whether the vibrations are equal as they should be. Clocks are often condemned because they stop, or because they do not keep good time, while these points and others are not in beat, the vibrations are not regular; hence it will not divide the time equally, and it is called a poor time-keeper, when the difficulty may be that it is not properly set up. A clock which will run when it is much out of beat is a very good one, and it must run very easily, because it has a great disadvantage to overcome, viz.: a greater distance from a perpendicular line one way than the

other in order that the verge may escape the teeth. A clock may be set up in perfect beat, but the shelf is liable to settle or warp, and get out of beat so gradually, that it might not be remarked by one not suspecting it, unless special notice was taken of it. This matter should be looked to when the clock stops.

I have explained the mode of setting up a clock with reference to putting it in beat, etc. Another essential point to be attended to is that the rod should hang in the centre or very near the centre of the loop in the crutch wire which is connected with the verge, and for this reason, if it rubs the front or back end of the loop, the friction will cause it to stop. To prevent this, set the clock case so that it will lean back a little or forward, as it requires. It sometimes happens that the dial (if it is made of zinc) gets bent in, and the loop of the crutch wire rubs as it passes back and forth. This should be attended to. It should be noticed, also, whether the crutch wire gets misplaced so that it rubs any kind of a dial; the least impediment here will stop a clock. The center of the dial should next be noticed. It sometimes happens that the warping moves it from its place, so that the sockets of the pointers rub, and many times it is the cause of the clocks stopping; this can be remedied by paring out the center on the side required.

Soft verges are no uncommon cause of clocks stopping, and those who travel to repair clocks generally overlook this trouble. A clock with a soft verge will run but a short time, because the teeth will dent into the face of the verge and cause a roughness that will certainly stop it. The way to ascertain this, is to try a file on the end of the verge; if you can file it it is soft; they are intended to be so hard that a file will not cut them. They can be hardened without taking off the brass ears or crutch wires, if you are careful in heating them; but the roughness on the faces caused by the teeth must be taken out in finishing. They must be polished nicely, and the polish-lines should run parallel with the verge: this may not seem to some necessary, but if the polished lines run crosswise you can hear it rub distinctly and it would cause it to stop.

It is very common to hear a clock make a creaking noise, and this leads inexperienced persons to think it has become dry inside. This is not so, and you will always find it to be caused by the loop of the crutch wire where it touches the rod; apply a little oil and it will cure it.

Some think a clock must be cleaned and oiled often, but if the foregoing directions are carefully pursued it is not necessary. I could show the reader several thirty-four hour brass clocks of my first and second years' manufacture (about twenty-two years since) which have been taken apart and cleaned but once — perhaps some of them twice. I have been told that they run as well as they did the first year. Now these are the directions which I should lay down for you to save your money, and your clocks from untimely wearing out. If you see any signs of their stopping — such as a faint beat, or if on a very cold night they stop, take the dial off, and the verge from the pin, wipe the pin that the verge hangs on, the hole in the ears of the verge, and the pieces that act on the wheel; also the loop of the verge wire where it connects with the rod, and the rod itself where the loop acts. Previous to taking off the verge, oil all the pivots in front; let the clock be wound up about halfway, then take off the verge, and let it run down as rapidly as it will, in order to work out the gummy oil; then wipe off the black oil that has worked out and it is not necessary to add any more to the pivots. Then oil the parts as above described connected with the verge and be very sparing of the oil, for too little is better than too much. I have never used any but watch oil. You may think that the other oils are good because you have tried them; but I venture to say that all the good they effected was temporary and after a short time the clock was more gummed up than it was before. Watch oil is made from the porpoise' jaw, and I have not seen anything to equal it. You may say why not oil the back pivots? They do not need it as often as the front ones, because they are not so much exposed, and hence, they do not catch the dust which passes through the sash and through the key holes that causes the pivots to be gummy and gritty. The front pivot holes wear largest first. A few pennys' worth of oil will last many years.

It is necessary to occasionally oil the pulleys on the top of the case which the cord passes over. If this is not done the hole becomes irregular, and a part of the power is lost to the clock. Common oil will answer for them. With regard to balance-wheel clocks, it is more difficult to explain the mode of repairing, to the inexperienced. With reference to oiling, use none but watch oil.

Since these directions were written nearly sixty years ago, a few comments may be in order. If the verge is too soft,

it is hardly work for an amateur to try to harden it. One is too likely to spoil things. Furthermore, slight indentations in the verge from long wear do not seem to be as fatal to running as would here appear. Ten years is too long a time to allow a clock to run without any oiling or cleaning. But few would do it.

The accuracy of one of these shelf clocks naturally depends somewhat upon its condition. If the movement has been well cleaned and oiled and put in good condition, it ought to keep time within two or three minutes a week. As this is being written, there are five of these shelf clocks within hearing distance of the writer and each one of them keeps within the limit just stated.

CHAPTER XXIV

THE CARE, REPAIR, ACCURACY, AND TESTING OF WATCHES

The present chapter deals with the care, repair, cleaning, accuracy, and testing of the modern watch. Watch factories began to make their appearance shortly after 1850, so that this date may be taken as the dividing line between antique and modern watches. A watch made after 1850 may thus be considered modern. Old watches will not be considered. They are nearly all in museums or private collections and most of them are not kept in running order. If one were to be repaired it should of course have the best skill obtainable. Too much renovating should not be done. An antique watch which is two thirds new is not a treasure. And a worse practice still is to combine the parts of two or three old watches to make one that is presentable. Their accuracy in most instances is quite inferior to modern watches. If one wants an accurate timekeeper, buy a first class modern watch. An antique watch should be considered a fossil from the past and treated as such.

This chapter also completes the treatment of the watch to which seven previous chapters have been devoted. These were Chapter VIII, "On the Construction of the Watch of To-day"; Chapter IX, "On the History of Spring-driven Clocks and Clock-watches from 1500 to 1658"; Chapter XIII, "On the History of Watches from 1600 to 1800"; Chapter XIV, "On the History and Construction of the Individual Parts of Watches"; Chapter XV, "On the Attachments to Watches and Complicated Watches"; Chapter XXI, "On the History of Watchmaking in America"; and Chapter XXII, "On Modern European Watchmakers." These seven chapters, together with what follows, could be considered a separate treatise on the watch apart from the rest of the book. If these chapters

are not fresh in mind, it would be profitable to read them again as an introduction to the material here given. This is particularly true of Chapters VIII and XIV.

The care of a modern watch. — There are several matters in connection with the care of a modern watch to which attention should be given. This is especially true if it is an expensive high-grade watch which is expected to keep good time. As regards winding there are three precepts which can be laid down: Wind regularly, wind in the morning, do not wind too tight. The reason for winding regularly is in order to use the same amount of uncoiling on the part of the mainspring each day. When the mainspring is wound up tight, it pulls with its greatest force and causes the balance to swing through a larger arc. When nearly run down it pulls with much less force and the balance swings through a smaller arc. The purpose of the adjustment to isochronism was to make the time of swing of the balance the same regardless of the arc through which it swings. This can be done within limits but not to an indefinite extent. For example, it can be done for the change of arc during 24 or 28 hours of running. It cannot be done for the 36 to 42 hours between fully wound up and run down. This can be shown graphically by means of the isochronism curves of watches, three of which are shown in Fig. 300. These curves are obtained by winding a watch up and then noting how much it has gained or lost at the end of each hour until it has run down. The temperature and position of the watch must be kept the same during the test and there must of course be some accurate source of time from which to determine the error. The first two watches had been well adjusted for isochronism while the last had been poorly adjusted. The first watch was losing about a second a day, but it did it regularly throughout the 24 hours. It ended up by being nearly 30 seconds slow before it ran down. This watch would be a fine timekeeper if wound regularly every 24 hours, but think of the effect if it should be wound at the end of 33 hours, then at the end of 18 hours, then at the end of 21, then at the end of 28, etc. Its rate would be

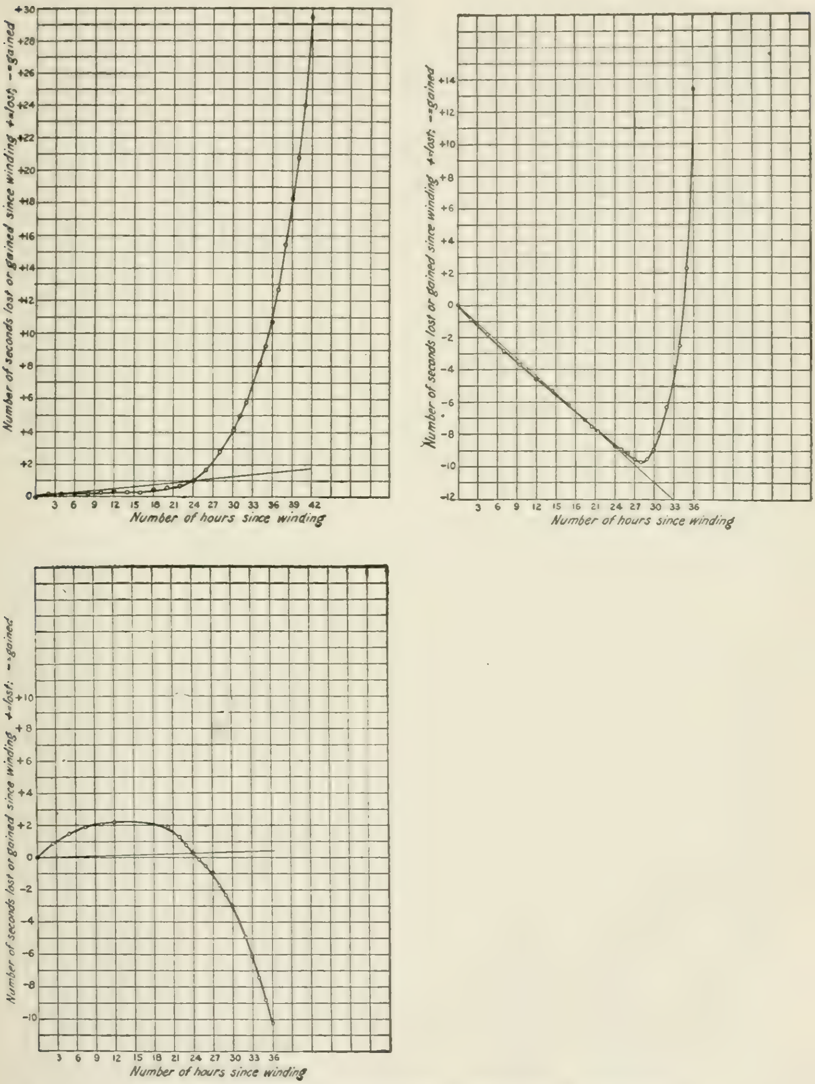


FIG. 300. — THREE ISOCHRONISM CURVES FOR WATCHES.
(Bureau of Standards, Washington, D. C.)

apparently very variable. The second watch was gaining about nine seconds a day but it was doing it regularly throughout the 24 hours and in fact until about 28 hours. It was well adjusted to isochronism. It could have been easily regulated so as not to have gained quite as much as nine seconds a day. It ended up by being over 13 seconds slow. Here if the watch had been wound within four hours of a regular time there would have been no apparent change of rate due to lack of regularity in winding. The third watch was losing only about three tenths of a second a day but it was very poorly adjusted to isochronism. Twelve hours after winding it was more than two seconds slow. Here again any lack of regularity in winding would make the rate appear quite irregular. All these facts about the three watches are clearly brought out in the figure. Anyone can obtain the isochronism curve for his own watch if he has access to an accurate source of time and it is very interesting to determine it. Nothing can make one realize better the importance of regular winding.

There are three reasons why a watch should be wound in the morning. In the first place one's habits of life in the morning are more regular than at night and thus a watch would be wound more regularly if wound in the morning. Secondly, the spring is then taut and pulling with its greatest force while the watch is subjected to the jars and use of the day. Thirdly, there is perhaps less danger of breaking the mainspring. Mainsprings sometimes break at night just after a watch has been taken from a warm pocket, wound up tight, and then put in a cooler place. The reason is obvious. The mainspring contracts due to the cold and, since it is already tightly coiled, it breaks due to the strain. If wound in the morning when taken from a cold place and put into a warm pocket, there would be no such danger.

There are also three reasons why a watch should not be wound too tight. The oil is squeezed out, too much tension is put on the escapement, and there is danger of breaking the mainspring, particularly if wound at night. So great are these dangers that some watches have stop work to

prevent overwinding and some have a recoiling click to let down the mainspring just a little after it has been wound up tight. Some consider that the uniformity of rate of a watch can be improved by winding it every twelve hours. With some watches this would perhaps be true. It would be necessary to wind it regularly, however. On the whole, it is not worth the additional trouble. The habit of winding a watch a few turns every time it is taken out of the pocket is also not to be recommended.

Setting a watch is also something which should be done with care. There is a myth that a watch should not be set back. Any American-made watch can be set back as well as forward. This is not the case, however, if there are complicated attachments or if it has a chronometer escapement. Sometimes the second hand stops or even moves back if the watch is set back. If this is the case, then the watch should never be set back. A watch should be set as little as possible, as there is a tendency to cause a change of rate. The question is often asked how the second hand can be set. There is no good way. The correct answer to the question is: Do not set the second hand, but set the minute hand to it. For example, your watch is gaining. Set the minute hand to agree with the second hand. When it has become 30 seconds fast, set it back a whole minute. It will then be 30 seconds slow and the minute hand will still agree with the second hand. Do not set it again until it has gained a minute and is 30 seconds fast once more. This is the only proper way to treat a watch. It is then never more than 30 seconds out, the minute hand always agrees with the second hand, and setting has been reduced to a minimum. But there may be times when it is very necessary or desirable to set the second hand. A jeweler would open the case at the back, put a soft brush against the balance wheel, thus stopping the watch, and wait until the second hand was in the desired position. The minute hand would then be set to the second hand. This procedure is hardly advisable for any amateur. To open the case and push the second hand around with a knife blade or other

instrument is nothing short of butchery. It loosens the second hand on its arbor, it strains the escapement, and often changes the rate. Sometimes the second hand is held fast by a knife blade or some object and then released at the proper moment. This does not strain the escapement but tends to loosen the hand on its arbor. There is still another way which is troublesome but ingenious and can be used by an amateur. If a watch is hung on a nail or similar support it usually swings a little backward and forward in unison with the motion of its own balance. This will usually make a watch gain or lose quite a few seconds in a day. Which it does, depends upon the individual watch. Each person therefore must try out his own watch before using this method for setting. For example, if hanging up a watch and allowing it to swing causes it to lose twelve seconds a day, then if one wished to set the second hand back three seconds it would only be necessary to hang up the watch for six hours.

A watch should also be regulated as seldom as possible. It is far better to let it gain or lose several seconds a day than to constantly try to have its rate very small. It is better to let a jeweler do the regulating when necessary. After a watch has had its regulator touched it will be several days before it has settled down to the new rate.

A watch should also be guarded against magnetic influence. This means that one should not go within five or ten feet of a powerful dynamo or motor. It also means that it would be better not to go near magnetized iron or a wire carrying a current. This, however, would be impossible in everyday life. A watch must be used without thought, but not abused. To stand over a dynamo would be to abuse it. One cannot avoid trolley cars, electric fans, and the like. If a watch becomes magnetized it can be readily demagnetized. Most jewelers have a piece of apparatus for doing this. If a watch is magnetized or not can be detected by means of a little compass. Attempts have been made to replace the balance spring and the inner portion of the balance rim with some non-magnetic metal or alloy.

Such watches have, however, not proved to be quite as satisfactory as those in which steel is used for these parts. A watch which has a hunting case is a little more protected against magnetic influence than an open face watch. The reason is this. If the watch has a hunting case there is a latch spring for holding the case shut and a case spring for opening the case. Only the tips of these springs are visible, but there is a considerable mass of iron around the movement inside the case and this acts as a protective ring against magnetic influence. A gun metal case, which is made of iron, is also a much better protection against magnetic influence than one of gold or silver.

A watch should also be guarded against lint and dirt. This means that nothing else should ever be put in the pocket in which the watch is habitually carried. This applies particularly to a tobacco pouch or handkerchief. It is better to keep a watch in a little protective chamois case. This keeps out dirt and lint, prevents the case from being scratched, and keeps the watch in the same position in the pocket. The case should close tightly and the movement should almost never be opened.

Temperature changes, jars, and changes in position should be avoided as far as possible. Here again the watch must be used without thought, but not abused. Never throw your vest across the room with your watch in the pocket. A watch will keep better time if worn in a pocket above the waist line, if not used as a wrist watch, if left behind when one climbs a mountain, and if placed on edge pendant up at night. Most people do not wish to bestow so much thought on their watches, however.

Repairing a modern watch. — Breaking a mainspring is without doubt the commonest accident that befalls a watch. Statistics have been prepared to show the cause of breaking and the season of the year and the time of day when the break usually occurs. Taking a watch from a warm pocket, winding it very tight, and then placing it on something cold, probably causes many breaks. They also break on account of some unusually heavy jar. It is often said that

more break during thunder showers than at other times. One naturally suspects that the electrical discharges are in some way responsible but the exact connection is not evident. More mainsprings break during the summer than during the winter. Moisture and high temperature, through promoting rust, are probably chiefly responsible for the weakening of mainsprings and their ultimate breaking.[1] Putting in a new mainspring requires, of course, the services of a good jeweler. No amateur should attempt to repair or clean any watch except an old one which has ceased to be valuable or a new one which has cost less than $2.

A broken balance staff is probably the next common ailment. Sometimes only the pivots are bent. This always results from a violent jar. It is very unfortunate when this occurs. It is an easy matter to put in a new balance staff, but the position adjustments are thereby destroyed and sometimes the adjustment to isochronism. A good watch after a new balance staff has been put in ought to be adjusted again by an expert, and this would require several weeks.

A cracked jewel is also a common ailment. A new jewel can be readily put in and the watch is as good as ever.

Many watches are dropped and there can be no greater misfortune to a good watch. Pivots are bent, jewels cracked, adjustments destroyed, and parts thrown out of alignment. A good watch that has been dropped ought to go back to the factory and be set up and adjusted all over again. If a watch drops it is better for it to fall on a side than on an edge. More jewels may be cracked, but there is less danger of bending pivots and spoiling alignments.

Cleaning and oiling a watch. — In time a watch movement becomes dirty and the oil deteriorates and becomes hard and gummy. If allowed to go too long, the rate will become irregular and the watch will finally stop. All jewelers and watchmakers claim that a watch should be cleaned and oiled every year or eighteen months, even if it

[1] S. R. Williams, "A seasonal breakage of mainsprings in watches," *School Science and Mathematics*, Vol. XXI, Nov., 1921.

shows no irregularity of rate. They argue that the oil begins to deteriorate at the end of six months and that, by the end of the year or a little more, the pivots have become dry and there is then great danger of cutting them. As a matter of fact, people take these statements "with a grain of salt," think that the jewelers are trying to make work for themselves, and watches are allowed to go until they actually stop or something breaks and there is need of repairs. If nothing happened it would probably be eight or ten years before the watch was taken to a jeweler just to be cleaned and oiled, and watches are apparently none the worse for this neglect. Here we have the statements of experts on the one hand and popular practice on the other. It is without doubt true that a good watch should not be allowed to go more than four of five years without cleaning and oiling, even if the rate remains regular and there is no apparent need of a trip to the jeweler. How much oftener it should be taken, each watch owner must decide for himself. And as a matter of fact, it depends quite a little on the owner and the kind of use it gets.

When a watch is taken to a jeweler to be cleaned and oiled, the procedure is about as follows: The movement must first be taken out of the case. All movements come out of the front or dial side. There are sometimes a couple of dog screws at the back which must be given a half turn. A dog screw is one which has nearly half of the head cut away. Usually the screws which hold the movement must be taken entirely out. Usually one or more screws in the pendant must be removed and perhaps the stem pulled out. The movement is held in the case in slightly different ways, but it is always easy to see how to take it out. Next the hands and dial are removed and also the under-the-dial wheels. The mainspring is now let down and the balance removed. The various bridges are next removed and the movement taken entirely to pieces. If there are cap jewels these must be taken off, and the hole jewels, if in settings, particularly those for the balance, the pallet arbor, and the escape wheel, are usually

removed. As the watch is being taken down each part will be examined to see that it is all right and that there is no need of repairs. The jeweler will also note if the parts are marked so that they may be placed in the same position again when the watch is set up. If not so marked, the jeweler often marks them. This applies particularly to the jewels. If there are any necessary repairs, these are now made before the parts are cleaned. The Waltham Watch Company in a very interesting advertising pamphlet entitled "Helpful Information for Watchmakers," describes the proper method for cleaning a watch movement. It states:

"Put all the parts (except the balance) in benzine, to remove oil and greasy matter. After the oil is cleaned off, string a few pieces at a time on a wire loop, or hook and wash in hot water with a medium soft brush and castile soap. While the parts are on the hook, dip in a solution of cyanide of potassium [1] for one to two seconds; rinse thoroughly in clean water, immerse in alcohol for about ten seconds, and dry in warm boxwood sawdust. When the mainspring is taken out of the barrel it should be handled carefully, and no attempt made to straighten it out. If the oil on it appears gummy, it should be cleaned off thoroughly with benzine, but if the oil appears good it is better to only wipe the spring with a piece of cloth by folding it around the spring and sliding it along without straightening the spring. After the spring is put back in the barrel, which, by the way, should be done with a good mainspring winder, it should be oiled with good quality watch oil in sufficient quantity to insure thorough lubrication without risk of spreading on the outside of the barrel.

The escapement jewels, after going through the benzine, should be taken, one at a time, with a pair of specially

[1] The cyanide solution referred to should be made in the proportion of 7 ounces, avoirdupois, to one gallon of water, and this solution should be renewed as soon as it shows a tendency to turn dark. Cyanide of potassium is a virulent poison, and great care must be taken in handling it. It is considered deadly if reaching an open scratch in the skin. The fumes should also be avoided. A good way of keeping both the cyanide and alcohol for cleaning watches is in one gallon specimen or candy jars, with ground glass covers, and marked with conspicuous warning labels.

prepared tweezers, to avoid their snapping away, and held against a flat board, or a large piece of cork, and brushed thoroughly, one side at a time, with a fine tooth-brush dipped in alcohol. After the brushing dip the jewel in clean alcohol, and dry between linen cloths.

After going through this process, we are reasonably sure that the jewels are clean, but we recommend, to make it absolutely sure, a careful rubbing with a piece of peg wood, which has been pointed so as to go through the holes, and also one which is specially shaped for rubbing the cups in the jewels. After the jewels and endstones are put back in the plates, but before the movement is put up, the cap jeweled holes should be oiled. This is an operation which should be done with utmost care, as it is very important to give the right quantity of oil. The consequence of too much oil at these points is almost as bad as lack of oil. For the purpose of retaining a sufficient amount of oil in the pivot holes, we take advantage of a natural phenomenon which is called capillary action. This action is, roughly stated, the tendency of liquids to run in between surfaces which are nearly in contact, and also to run upwards quite rapidly in very small tubes, against the force of gravity.

The capillary action is strikingly illustrated in the wick of a lamp in which the close proximity of the fibers to each other, acting like capillary tubes, causes the oil to run upwards through the wick as fast as it burns at the top end of it. In view of these facts, and by the aid of the drawing below (Fig. 301), we shall endeavor to explain why sometimes a pivot will run dry in a short time because we gave too much oil in the pivot hole. Looking at the drawing we find that the hole jewel

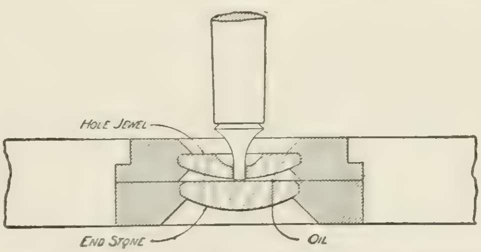


FIG. 301.—OILING THE PIVOTS OF A WATCH. (The Waltham Watch Co.)

is convex on the side towards the endstone, and also that there is a certain distance between the two jewels. This space is usually made about .02 to .03 mm., and is for the purpose of providing a reservoir for the oil.

And the convex shape of the hole jewel tends to keep the oil around the pivot, being attracted by the close space nearest the hole, by virtue of the capillary action referred to above. Now if we should give so much oil that it would fill the space to the edge of the hole jewel, it would immediately be attracted by close space between the settings, which would pull it away and leave the pivot without a reserve supply of oil. The oil between the jewels ought to show in the proportion indicated on the drawing, or nearly so. For applying the oil we recommend an oiler made of small wire, about .40 mm. diameter, preferably gold, which is filed tapering almost to a point, and the end flattened by hammering. This flattened point will hold the oil in a fairly definite quantity, so we know how much we deposit in the hole. After the oil has been put in the cup of the jewel, if it does not run down, we should coax it to do so by inserting the point of a pivot broach, and not consider the job done until we know by inspection that the oil has filled in properly between the jewels.

The cleaning of the balance with the hairspring requires special care, as it cannot be brushed safely. The usual method is to put it on a hook and dip it for a few seconds, first in water, then in cyanide; rinse in water, dip in alcohol, and dry carefully in sawdust. The balance may be buffed afterwards with a string of chamois skin held in a wire bow, to brighten the rim, as well as the screws. After the balance has been cleaned, it should be examined carefully for any minute fiber that might have caught in the balance screws, or particles of sawdust in the slots of the screw heads. When cleaning a balance, if the jewel pin is set with shellac, and also when cleaning pallets, care must be taken not to leave them in the alcohol very long, as it would dissolve the shellac and loosen the jewels.

After the movement is set up all the rest of the pivots

should be oiled and also the pallet stones or the escape wheel teeth. But do not oil the jewel pin or the safety action. In the stem-winding works, all the bearing surfaces should be oiled, including the square of the winding arbor, where it runs through the clutch. Here it may be well to emphasize the importance of taking good care of the oil which we use. It should be kept in a dark and cool place, and we should put only a drop or two at a time in our oil cup. A small agate cup with boxwood cover, such as is furnished by dealers in watch tools, is best adapted for use on the bench. This should always be cleaned before putting in fresh oil, and covered when it is not in use to prevent contamination of the oil by dust, etc."

After the movement has been cleaned and oiled, the case should be taken in hand and dusted out and cleaned before the movement is put back. After the movement has been put back in its case, examine everything thoroughly to see that nothing is wrong. Be sure that the hands do not catch on each other or touch the dial or crystal. Be sure that the winding and setting mechanism works properly. Be sure that the escapement is in beat and that no part of the movement, particularly the balance, is interfered with by the case.

Many jewelers do not "wet clean" a watch but "dry clean" it instead. After the movement has been taken down, each part is carefully brushed with a suitable brush, which is cleaned by being rubbed from time to time on prepared chalk. The parts are held in tissue paper during this brushing. All pinions and jewels are carefully cleaned with peg wood. If the old oil is not particularly hard and dry, one method is perhaps as good as the other; it is largely a matter of care.

A word should be said about the quantity and quality of the oil used. A small drop is more than enough to oil an entire watch. Only the best watch oil should be used. A satisfactory watch oil must remain liquid at low temperatures, must not evaporate rapidly even at high temperatures, must not corrode on metal, and must not become

gummy. Olive oil has been tried and also various vegetable oils, but they become gummy and turn green on brass. Neat's foot oil is also unsatisfactory and the mineral oils evaporate too quickly. Fish oil is considered the best, and that taken from the jaw of a particular species of porpoise, known as the black fish, is considered the very best. Great care must be taken in extracting it. William F. Nye, who is the largest and best known manufacturer of watch oil in this country, tries out his oil at New Bedford, Mass., and in the following winter sends it to St. Albans, Vt., where it is filtered at a temperature many degrees below zero.

The accuracy of modern watches. — How accurate is the modern watch? How closely will it keep time? These are questions that are often asked. There is a great popular interest in this matter. In the first place it must be stated that the accuracy depends upon the grade of the watch and upon the care which it receives. The number of jewels in a watch is a rough index of its grade. It will be remembered that twenty-three is the largest number of jewels that a watch can have. Many manufacturers of watches consider that it is unnecessary to jewel the mainspring barrel arbor and put only twenty-one jewels in their very best watches. The number of jewels runs from twenty-three or twenty-one down to seven, which is the smallest number put in a watch. No account is here taken of the watches selling from $1 to $5 or $6 when new. These may contain four jewels, but usually none at all. The number of jewels is not an absolute index of the goodness of a watch. A seventeen-jewel watch, carefully adjusted to temperature, isochronism, and position would run far better than a twenty-one-jewel watch which had been adjusted but little. The amount of adjusting, however, is usually in proportion to the number of jewels, so that the number of jewels is, in most instances, a fair index of the grade of watch. As regards care, the watch should be used without thought, but not abused. It should be wound regularly, preferably in the morning, and not too tight. Dynamos and excessive jars should be avoided and it should be cleaned and oiled at

reasonable intervals. It is expected that it will receive ordinary everyday use without "babying" it. The accuracy of a watch is judged by the constancy or uniformity of the rate for a limited period. If a watch gains ten seconds a day, but gains this same amount day after day, without variation, it is an extremely accurate watch. It could easily be regulated to gain less if desired. In fact, most good watches are regulated to gain or lose less than a second a day on the average. The test of accuracy is how constant the rate remains.

The question as to the accuracy of modern watches can now be answered. A seven-jewel watch, cared for as described, ought to maintain its daily rate for a period of two months within about twenty seconds of constant. A seventeen-jewel watch adjusted to temperature, isochronism, and at least three positions, should maintain its daily rate within about three seconds of constant. A twenty-three- or twenty-one jewel watch, fully adjusted to temperature, isochronism, and to five positions, perhaps six, is supposed to maintain a constant rate within a second a day for a period of at least two months. This means, for example, that if the watch is losing 1.4 seconds a day, it will never lose less than 0.4 seconds or more than 2.4 seconds daily during the two months. As a matter of fact, but few watches will live up to this requirement. A watch made with the care and attention given to the $750 watch of the Waltham Watch Company, or a foreign made watch of similar grade, ought to maintain its daily rate within a few tenths of a second of constant. There are several places in the world where watches are tested and the results of these tests have been published for many watches. The tests, however, are always carried on under special conditions. There is almost no available data as to the actual behavior of watches under the trying conditions of everyday use.

The following tables contain the record of a twenty-one-jewel, sixteen-size, hunting-case watch made by one of the large well-known American watch factories. This watch is about twelve years old, and was cleaned and oiled about

two years before its record begins. It had been purchased of a jeweler and was a regular stock watch. It was wound regularly in the morning and never too tight. It had never been dropped. It was never taken near a dynamo or exposed to very violent unnecessary jars. It was used constantly during the two years and without thought. It was carried in a vest pocket in winter and a trouser pocket in summer. It was put down on a dresser at night, sometimes dial up and sometimes dial down. No attention was paid to temperature. It went on automobile rides and trips by train. It took long walks and went to the seashore. It shook the furnace and mowed the lawn. In short, it was used constantly without the slightest thought as to its condition. It was used as nearly every one uses his watch. In the table are given the date, the error on that date, and the daily rate. The source of time for determining the error was always the noon time signal, so no inaccuracies have crept in there. The second table contains the average rate for each month found by averaging the rates for the various periods during the month or any part of it.

It will be noticed in the first place that the watch has a large yearly change of rate. During the winter it gains about three seconds a day on the average and during the summer it loses about the same amount. The largest observed gaining rate was − 5.9 between Feb. 16 and 21, 1917, and the largest losing rate was 5.0 between July 27 and Aug. 2, 1917. This yearly change of rate results from a variety of causes. Temperature was perhaps the chief cause, although the temperatures to which the watch was exposed were not so very different as between winter and summer. A difference in the jars, due to different occupations, a difference of pocket in which the watch was carried, etc., are also large contributors to the change. The greatest change in rate between two successive periods was 3.7 between Nov. 20 and 27, 1917, and Nov. 27 and Dec. 7, 1917. Several two-month periods can be picked out when the various rates did not differ more than one second from the average for the period. For example, for the two months from Jan.

1916				
Oct.	10	4.0^{s}	Slow	
				+ 0.1^{s}
	17	5.0	Slow	
				− 0.3
	28	2.0	Slow	
				− 0.7
Nov.	3	2.0	Fast	
				− 1.4
	10	12.0	Fast	
				− 1.2
	17	20.5	Fast	
				− 2.7
	23	36.5	Fast	
	Set back 1^{m}			
	23	23.5	Slow	
				− 3.3
	29	3.5	Slow	
				− 4.4
Dec.	8	36.5	Fast	
	Set back 1^{m}			
	8	23.5	Slow	
				− 2.0
	13	13.5	Slow	
				− 3.1
	19	5.0	Fast	
				− 2.9
	23	16.5	Fast	
1917				− 3.5
Jan.	4	58.0	Fast	
	Set back 1^{m}			
	4	2.0	Slow	
				− 4.8
	8	17.0	Fast	
				− 4.5
	11	30.5	Fast	
	Set back 1^{m}			
	11	29.5	Slow	
				− 5.0
	15	9.5	Slow	
				− 4.8
	18	5.0	Fast	
	Run down and set			
	22	24.0	Slow	
				− 5.4
	27	3.0	Fast	
				− 5.7
Feb.	2	37.0	Fast	
	Set back 1^{m}			
	2	23.0	Slow	
				− 4.3
	5	10.0	Slow	
				− 4.0
	12	18.0	Fast	
				− 4.3
	16	35.0	Fast	
	Set back 1^{m}			

1917				
Feb.	16	25.0	Slow	
				− 5.9
	21	4.5	Fast	
				− 5.7
	26	33.0	Fast	
	Set back 1^{m}			
	26	27.0	Slow	
				− 5.2
Mar.	3	1.0	Slow	
				− 2.7
	10	18.0	Fast	
				− 2.4
	15	30.0	Fast	
	Set back 1^{m}			
	15	30.0	Slow	
				− 4.1
	19	13.5	Slow	
				− 3.7
	28	20.0	Fast	
				− 3.8
Apr.	2	39.0	Fast	
	Set back 1^{m}			
	2	21.0	Slow	
				− 4.0
	9	7.0	Fast	
	Run down and set			
	13	33.0	Slow	
				− 2.7
	20	14.0	Slow	
				− 2.0
	27	00.0	Fast	
				− 3.5
May	5	28.0	Fast	
				− 4.0
	10	48.0	Fast	
	Set back 1^{m}			
	10	12.0	Slow	
				− 1.7
	17	00.0	Fast	
				− 2.0
	24	14.0	Fast	
				− 2.3
	30	28.0	Fast	
				− 1.8
June	6	40.5	Fast	
	Set back 1^{m}			
	6	19.5	Slow	
				− 0.9
	11	15.0	Slow	
				+ 1.0
	16	20.0	Slow	
				+ 1.1
	23	28.0	Slow	
				+ 1.2
	28	34.0	Slow	
	Set ahead 1^{m}			

1917				
June	28	26.0	Fast	
				+ 0.8
July	10	16.0	Fast	
				− 1.1
	18	25.0	Fast	
				+ 3.0
	27	2.0	Slow	
				+ 5.0
Aug.	2	32.0	Slow	
				+ 3.0
	6	44.0	Slow	
	Set ahead 1^m			
	6	16.0	Fast	
	Run down and set			
	25	15.0	Slow	
				+ 4.9
Sept.	6	74.0	Slow	
	Set ahead 1^m			
	6	14.0	Slow	
				+ 3.4
	19	58.5	Slow	
	Set ahead 1^m			
	19	1.5	Fast	
				+ 2.8
	21	4.0	Slow	
				+ 3.6
Oct.	2	44.0	Slow	
	Set ahead 1^m			
	2	16.0	Fast	
				+ 2.7
	13	14.0	Slow	
				+ 1.8
	18	23.0	Slow	
				+ 4.0
	22	39.0	Slow	
	Set ahead 1^m			
	22	21.0	Fast	
				+ 1.4
	30	10.0	Fast	
				− 0.6
Nov.	6	14.0	Fast	
				+ 0.1
	13	13.0	Fast	
				+ 0.3
	20	11.0	Fast	
				+ 0.3
	27	9.0	Fast	
				− 3.4
Dec.	7	43.0	Fast	
	Set back 1^m			
	7	17.0	Slow	
				− 2.3
	14	1.0	Slow	
				− 2.9
	26	34.0	Fast	
	Set back 1^m			
	26	2.60	Slow	

1918				− 2.6
Jan.	2	8.0	Slow	
				− 2.7
	10	13.5	Fast	
				− 3.3
	19	43.5	Fast	
				− 1.1
	28	53.5	Fast	
	Set back 1^m			
	28	6.5	Slow	
				− 1.1
Feb.	9	6.5	Fast	
				− 3.9
	15	30.0	Fast	
	Set back 1^m			
	15	30.0	Slow	
				− 1.3
	28	13.0	Slow	
				− 0.2
Mar.	9	11.0	Slow	
				− 0.6
	21	4.0	Slow	
				− 0.1
	28	3.0	Slow	
				− 0.6
Apr.	10	4.0	Fast	
				+ 1.7
	20	13.0	Slow	
				+ 0.9
	30	22.0	Slow	
				− 0.9
May	7	16.0	Slow	
				0.0
	15	16.0	Slow	
				0.0
	20	16.0	Slow	
	Run down and set			
	21	25.0	Slow	
				+ 0.2
	31	23.0	Slow	
				+ 1.1
June	7	31.0	Slow	
				− 0.2
	20	28.0	Slow	
				− 2.9
July	5	16.0	Fast	
				+ 0.8
	22	1.5	Fast	
				+ 2.9
	29	19.0	Slow	
				+ 2.1
Aug.	13	51.0	Slow	
				+ 3.3
	26	94.0	Slow	
				+ 2.2
Sept.	7	120.0	Slow	
	Set ahead 2^m			

1918				1918			
Sept. 7	0.0			Oct. 4	25.0	Slow	
			+ 2.9				+ 2.0
16	26.0	Slow		17	51.0	Slow	
			+ 3.3	Set ahead 1^m			
27	62.0	Slow		17	9.0	Fast	
Set ahead 1^m							− 0.6
27	2.0	Slow		25	14.0	Fast	
			+ 3.3	Mainspring broke			

	1916–1917	1917–1918	Difference
October	− 0.3	+ 1.9	2.2
November	− 1.9	− 0.7	1.2
December	− 3.2	− 2.8	0.4
January	− 4.8	− 2.2	2.6
February	− 5.0	− 1.6	3.4
March	− 3.6	− 0.4	3.2
April	− 3.2	+ 0.3	3.5
May	− 2.5	− 0.3	2.2
June	+ 0.2	− 0.7	− 0.9
July	+ 1.9	+ 0.7	− 1.2
August	+ 4.3	+ 2.5	− 1.8
September	+ 3.7	+ 2.9	− 0.8

4, 1917, to March 3, 1917, all the values of rate fall between − 4.0 and − 5.9. It will also be noticed, particularly by consulting the second table, that the watch has been going slow with time. At the end of the two years it was running nearly two seconds slower than at the beginning of the record. It will also be noticed that through thoughtlessness the watch was allowed to run down four times. This did not apparently change the rate in any way and there is no theoretical reason why it should.

A natural question to ask is how the record would appear if the rate had been determined every day. The difference in rate would of course have been greater. The differences, if the rate is determined every ten days, would be three or four times less than if determined every day. The longer the interval the more the irregularities are smoothed out. As an illustration compare Table II, where the rates are given for the month, with Table I, where they are given five or six times a month.

One often hears tales of an ordinary watch which has run a month or two and gained or lost only a couple of

seconds. This is usually a fabrication or else the person did not have access to an accurate source of time for comparison. Even if it were true, it would give no indication of the accuracy of the watch unless one knew its record during the month or two. Take the record of the watch here given as an illustration. On Feb. 28, 1918, it was 13.0 seconds slow, while on May 20 it was 16.0 seconds slow. Apparently it had lost only three seconds in twelve weeks, but its record between had not been so good.

One's thoughts naturally turn to the most accurate watch in the world and one wonders how accurately it would run under the trying conditions of everyday use. There are no published records to serve as a basis for estimation. Watch No. 36145, made by Paul Ditisheim of La Chaux-de-Fonds, holds the record to date (1920) at the Neuchâtel Observatory. It must be considered as one of the two or three most accurate watches in the world. The 45 values of rate during the tests (see page 484) are as follows:

− 0.2	0.0	− 0.3	− 0.5	− 0.8	− 0.7	− 0.1
− 0.3	− 0.4	− 0.3	− 0.4	− 0.7	− 0.7	− 0.1
− 0.4	− 0.3	− 0.4	− 0.3	− 0.9	− 0.8	− 0.2
− 0.4	− 0.5	− 0.6	− 0.3	− 0.3	− 0.8	− 0.2
− 0.6	− 0.6	− 0.5	− 0.5	− 0.3	− 0.2	− 0.3
− 0.4	− 0.2		− 0.7	− 0.0	− 0.1	
+ 0.1			− 0.5	− 0.1	− 0.0	
			− 0.9			

The watch was not carried, of course, but was placed in different positions and at different temperatures. It will be noticed that the rates all fall between $+ 0.1^s$ and $- 0.9^s$. It is safe to say that it would not run as well in actual use. It is also probably a safe guess that it would run from five to ten times as well as the watch whose long record was given above.

An interesting sidelight is also thrown on the question of the accuracy of the modern watch in actual use by the longitude determinations [1] which have been made in recent

[1] Ditisheim, Paul, "Détermination de la Différence de Longitude Greenwich-Paris par Transport de l'Heure en Avion." *Monthly Notices*, Vol. 80, p. 809, 1920.
Ditisheim, Paul, "Essai d'une Détermination de Différence de Longitude par Transport de l'Heure." C. R., t. 138, p. 1027, 1904.
Ditisheim, Paul, "Longitude Neuchâtel-Washington."

years by Mr. Paul Ditisheim. He has determined the difference of longitude between Neuchâtel and Paris, between Paris and Greenwich, and finally between Neuchâtel and Washington by transporting a number of his very accurate deck watches. The difference of longitude between Neuchâtel and Washington was found by conveying watches to be $5^h\ 36^m\ 4.0^s$. Telegraphic determinations give the value as $5^h\ 36^m\ 5.6^s$.

Testing watches. — In England watches were formerly tested at the Kew Observatory in Richmond. At present all rating work is carried on at the National Physical Laboratory at Teddington. In France watches are tested at the Observatory in Besançon. In Switzerland watches are tested at the Observatory in Geneva and at the Observatory in Neuchâtel.

The famous Kew Observatory was built by King George III in 1769 for observing the transit of Venus. It is situated in the Old Deer Park adjoining the Kew Gardens in Richmond, about ten miles west of the city of London. It is pictured in Fig. 302. The testing of watches was commenced here in 1884 and continued until 1912, when the work was transferred to the National Physical Laboratory at Teddington, near London. In all 15,301 timepieces were tested at Kew during the twenty-nine years from 1884 to 1912. It was stated in another place (page 432) that the three best of these were all submitted by Paul Ditisheim of La Chaux-de-Fonds, in Switzerland.

FIG. 302. — THE FAMOUS KEW OBSERVATORY BUILT IN 1769.

The trial of a watch entered for a Class A certificate occupies forty-five days, divided into eight periods of five days each, and five intermediate and extra days, in four of which the watch is not rated.

1st Period. Watch in vertical position, with pendant up, at the temperature of the chamber (kept at 60°–65° F.).

2d Period. Watch in vertical position, with pendant to the right, at the same temperature.

3d Period. Watch in vertical position, with pendant to the left, at the same temperature.

4th Period. Watch with dial up, in the refrigerator, at a temperature of about 40° F.

5th Period. Watch with dial up, at a temperature of 60°–65° F.

6th Period. Watch with dial up, in the oven, at a temperature of about 90° F.

7th Period. Watch with dial down, at a temperature of 60°–65° F.

8th Period. Same as the first, watch in vertical position with pendant up.

The intermediate and extra days during which the rate of the watch is not recorded, are at the commencement of the 4th, 5th, 6th and 7th Periods, which are extended one day each for that purpose.

Class A certificates are granted to watches whose performance is such that:

1. The average of the daily departures from the mean daily rate, during the same stage of trial, did not exceed two seconds in any one of the eight stages.

2. The mean daily rate while in the pendant-up position differed from the mean daily rate in the dial-up position by less than five seconds, and from that in any other position by less than ten seconds.

3. The mean daily rate was affected by change of temperature to an amount less than 0.3 of a second per 1° F.

4. The mean daily rate did not exceed ten seconds while in any position.

The formula used at Teddington for computing the relative merit of a watch is:

$$A = 20\,(2.00 - \alpha) + 4\,(10.00 - \beta) + \frac{200}{3}\,(0.300 - \gamma)$$

where α is the mean deviation of the daily rate, β is the mean deviation for change of position, and γ is the error of compensation for temperature change.

A perfect watch would thus receive 100 points. The record at Teddington to date (1920) is held by watch No. 45065, made by Paul Ditisheim of La Chaux-de-Fonds, which in the 1920 trials received 96.9. A copy of the certificate issued is shown on page 432.

In France timekeepers are tested at l'Observatoire National in Besançon. The testing work commenced here in 1885, and a yearly "Bulletin chronométrique" is issued which contains articles as well as the records of the timekeepers. The director of the observatory is M. A. Lebeuf.

Courtesy, The Observatory at Besançon.
FIG. 303. — THE OBSERVATORY AT BESANÇON WHERE WATCHES ARE TESTED.

This observatory, pictured in Fig. 303, is extremely well equipped and carries on work in Astronomy, Meteorology, and Seismology as well as in watch testing.

The tests for watches of the first class last 44 days and are as follows:

Period	Number of Days	Position	Temperature
1	5	Vertical, pendant up	15° C.
2	5	Vertical, pendant to right	15° C.
3	5	Vertical, pendant to left	15° C.
4	6	Horizontal, dial up	0° C.
5	6	Horizontal, dial up	15° C.
6	6	Horizontal, dial up	30° C.
7	6	Horizontal, dial down	15° C.
8	5	Vertical, pendant up	15° C.

To obtain a bulletin ten conditions must be fulfilled. The formula for computing the relative merit of a watch is:

$$S = \frac{400}{3}(0.75 - \alpha) + 40(2.50 - \beta) + 350(0.20 - \gamma) + 6(5.00 - \delta)$$

α is the mean deviation of the daily rate; β the mean deviation for change of position; γ, the error of compensation for one degree centigrade; δ, the deviation of the rate for the last period from that of the first. It will be seen that a perfect watch would obtain 300 points. The duration of the tests, the conditions for obtaining a bulletin, etc., are different for marine chronometers and for watches of the first, second, and third [1] class. They have also been changed from time to time.

In Switzerland testing work is carried on both at Geneva and at Neuchâtel. At the Observatoire de Genève testing work commenced in 1872 and an annual report is issued by the director, Raoul Gautier. The title is, "Rapport sur le concours de Réglage de Chronomètres" for the year in question. The so-called new formula used at Geneva is

$$N = 600\,(0.50 - m) + 150\,(2.00 - p) + 2000\,(0.150 - c) + 40\,(2.50 - r)$$

where m is the mean deviation of daily rate; p, the mean deviation for change of position; c, the error of compensation for one degree centigrade; r, the return to previous rate. It will be noticed that a perfect watch would obtain 1000 points.

Testing began at Neuchâtel in 1876 and is carried on at the Observatoire Cantonal. This observatory (Fig. 304) is very well equipped and is very active not only in watch testing but in Astronomical, Meteorological, and Seismological work as well. The director is Dr. L. Arndt and a "Rapport du Directeur suivi du Rapport Spécial sur le concours des Chronomètres" is issued each year. The tests for watches of the first class last 46 days and there are 11 periods.

[1] Tests for watches of the third class were suspended in 1913.

Period	Number of Days	Position	Temperature
1	4	Horizontal, dial up	18° C.
2	5	Horizontal, dial up	4° C.
3	5	Horizontal, dial up	18° C.
4	5	Horizontal, dial up	32° C.
5	5	Horizontal, dial up	18° C.
6	1	Vertical, pendant up	32° C.
7	5	Vertical, pendant up	18° C.
8	4	Vertical, pendant to left	18° C.
9	4	Vertical, pendant to right	18° C.
10	4	Horizontal, dial down	18° C.
11	4	Horizontal, dial up	18° C.

FIG. 304. — THE OBSERVATORY AT NEUCHÂTEL WHERE WATCHES ARE TESTED.

The first day of periods 2, 3, 4, 5, 7, and period 6 do not count. There are nine conditions to be fulfilled to obtain a bulletin. The formula used is:

$$A = \frac{100}{eE + cC + dD + pP + rR}$$

E is the mean departure of the daily rate; C, the temperature coefficient; D, the error of compensation; P, the mean departure corresponding to a change of position; R, the

change of rate. The values of e, c, d, p, and r are different for marine chronometers, deck watches, watches of the first class, and watches of the second class. For watches of the first class $e = 13.3$, $c = 13.3$, $d = 1.5$, $p = 4$, and $r = 1.7$. It will be noticed that a perfect watch would obtain an infinitely large number of points.[1] The record at Neuchâtel to date (1920) is held by Ditisheim's No. 36145, which in 1912 gained 40.6 points. A copy of the certificate is reproduced on page 433.

The following table contains the number of timekeepers submitted for tests each year since 1900 at Teddington,

	Teddington (Kew)		Besançon[1]		Geneva		Neuchâtel	
	Number Submitted	Bulletins Awarded	Number Submitted	Bulletins Awarded	Number Submitted	Bulletins Awarded	Number Submitted	Bulletins Awarded
1900	457	393	711	519	528	429	409	346
1901	399	342	784	537	306	224	289	233
1902	563	446	690	519	359	275	246	184
1903	506	397	730	456	266	214	204	150
1904	472	382	770	587	235	188	557	467
1905	498	421	941	742	287	248	600	445
1906	363	295	868	657	377	290	511	378
1907	420	321	1050	785	311	239	637	507
1908	334	266	1104	767	445	367	684	486
1909	488	381	1195	872	320	241	637	475
1910	568	450	1356	917	302	237	646	462
1911	683	486	1593	1181	256	204	643	427
1912	579	462	1491	1093	239	200	575	385
1913	798[2]	588	783	544	324	257	568	411
1914	428	351	190	141	296	238	828 (1914–1915)	605 (1914–1915)
1915	463	367	86	74	153	136		
1916	458	344	187	138	106	87	447	357
1917	276	212	165	109	132	115	408	338
1918	310[3]	236	203	144	116	93	497	393
1919	320[4]	269	275	223	112	106	510	430
1920			245	184	88	81	515	428

[1] The period at Besançon is really from May 1st of the year in question until April 30th of the following year.
[2] 15 months, Jan., 1913, to March 31, 1914.
[3] 18 months, April 1, 1918, to Sept. 30, 1919.
[4] Oct. 1, 1919, to Sept. 30, 1920.

[1] In order to understand fully the methods of testing a timekeeper and of computing the items which enter into the formulas one should obtain and study carefully a file for at least ten years of the publications of these various observatories. One would also then be able to judge of the relative rigorousness of the tests at the various observatories.

Besançon, Geneva, and Neuchâtel, and also the number of bulletins which have been awarded. These figures include marine chronometers as well as watches. Watches are, however, greatly in the majority. At Teddington the number of marine chronometers submitted averages something less than 100; at Besançon 4 to 6; at Geneva 1 or 2; and at Neuchâtel some 50.

The following table contains for the last few years the watch which stood first, the firm that made it, and the number of points that it obtained.

Year	Watch Number	The Firm That Made It	The Number of Points Obtained
		TEDDINGTON TESTS	
1917–1918	36,162	Paul Ditisheim at La Chaux-de-Fonds	96.2
1918–1919		Fabrique des Longines at St.-Imier	95.5
1919–1920	45,065	Paul Ditisheim at La Chaux-de-Fonds	96.9
		BESANÇON TESTS	
1907		Antoine frères	262
1908		L. Leroy et Cie	245
1909		Geismar et Cie	260
1910		L. Leroy et Cie	267
1911		J. Antoine	268
1912		Lipmann frères	259
1913		Doffe et Cie	262
1914		P. Lévy	258
		GENEVA TESTS	
1915		Patek, Philippe & Cie at Geneva	837
1916		Patek, Philippe & Cie at Geneva	861
1917		Vacheron & Constantin at Geneva	842
1918		Vacheron & Constantin at Geneva	849
1919		Patek, Philippe & Cie at Geneva	824
1920		Patek, Philippe & Cie at Geneva	842
		NEUCHÂTEL TESTS	
1914–1915	1,902,961	Fabrique de Montres Zénith at Le Locle	40.5
1916	1,556,750	Fabrique de Montres Zénith at Le Locle	33.8
1917	159,365	Paul Buhré at Le Locle	36.8
1918	46,878	Paul Ditisheim at La Chaux-de-Fonds	27.9
1919	1,014	Fabrique des Longines at St.-Imier	29.9
1920	64,996	Paul Ditisheim at La Chaux-de-Fonds	34.5

Watch testing in the United States. — In the United States the testing of watches was taken up at the Bureau

of Standards in Washington, D. C., in 1914. Full information about the tests is found in Circular No. 51 of the Bureau of Standards entitled: "Measurement of Time and Tests of Timepieces." A copy of the circular, which also contains an application blank for submitting a watch, can be obtained from The Government Printing Office, Washington, D. C., for 15 cents. Several paragraphs from this pamphlet are here quoted:

REGULATIONS GOVERNING THE TESTING OF WATCHES

GENERAL

1. Classes of Test. — Pocket watches will be received for rating under two classes of tests, designated as class A and class B. Class A is intended for watches of the better grades which come under the designation "Adjusted for five positions, temperature and isochronism." Class B is intended for watches which are designated as "Adjusted for three positions and temperature." Watches of either class may be submitted for rating in the other class of test than that under which they are designated, if desired. A watch which has been submitted for test under class A will be awarded a class B certificate, if the party submitting it so desires, in case its performance does not meet the requirements of class A but does conform to those of class B. The request for a class B certificate under such circumstances must be made, however, when application for the test is made. In such cases the full fee for a class A test must be paid. In addition to the class B certificate a report will be rendered showing wherein the watch failed to conform to the class A requirements.

2. Time of Tests. — The test under class A will require 54 days; that under class B will require 40 days. Tests will be held four times a year, the class A tests beginning on the second Tuesday in January, April, August, and October, while the class B tests will begin 14 days later in each case.

3. Cases or Mountings. — The watch movements may be mounted in regular cases of either open face or hunting style, or they may be submitted in exhibition or "skeleton" cases if fitted with dust-proof covers and provided with a stem for winding the watch. If watches are submitted mounted in regular cases, the name of the maker and maker's number of the case will be given on the certificate, unless request is made to the contrary.

4. Application for Test. — Application for the test of a watch must be made in advance of the beginning of the test. The application should be made on a blank which may be obtained from the Bureau upon request. A separate blank must be made out for each watch submitted, and all the information requested concerning each watch must be furnished so far as available.

5. Winding Before Test. — Watches delivered personally or by messenger considerably in advance of the beginning of the tests will be kept wound regularly until the trial begins. Watches shipped to the Bureau, upon being unpacked, will be wound and set. All watches will be kept in the vertical, pendant up position until the beginning of the trial.

CLASS A

6. Method of Test. — Watches submitted for test under class A will be run for 54 days in a series of periods in the positions and at approximately the temperatures given below, each period being of the duration indicated:

Period Number	Duration in Days	Position	Temperature
1	3	Vertical, pendant up	28°–30°C (82°–86°F).
2	3	Vertical, pendant right	Do.
3	3	Vertical, pendant left	Do.
4	3	Horizontal, dial up	Do.
5	3	Horizontal, dial down	Do.
6	3	....do	Do.
7	3	Horizontal, dial up	Do.
8	3	Vertical, pendant left	Do.
9	3	Vertical, pendant right	Do.
10	3	Vertical, pendant up	Do.
*11	3	....do	Do.
12	5	Horizontal, dial up	5°C (41°F).
		One intermediate day.	
13	5	....do	20°C (68°F).
		One intermediate day.	
14	5	....do	35°C (95°F).
		One intermediate day.	
15	3	Vertical, pendant up	28°–30°C (82°–86°F).

7. Tolerances. — Certificates will be granted to watches which in the above test give results within the following tolerances:

(1) The *mean deviation of daily rate* not to exceed 0.75 second.

(2) The *mean deviation for change of position* not to exceed 3.00 seconds.

(3) The *difference between the mean rates of any two positions* not to exceed 10.0 seconds.

(4) The *difference between the mean rates in the vertical, pendant up and the horizontal, dial up positions* not to exceed 5.0 seconds.

(5) The *difference between the mean rates in the horizontal, dial up and the horizontal, dial down positions* not to exceed 4.0 seconds.

(6) The *progressive change in rate in periods 1 to 10* do not exceed 3.00 seconds.

(7) The *recovery of rate* (period 15 minus period 1) not to exceed 6.0 seconds.

(8) The *isochronism error* not to exceed 3.0 seconds.

(9) The *difference of rate per degree centigrade between 5° and 35°* not to exceed 0.20 second.

(10) The *difference of rate per degree centigrade between 5° and 20°* not to differ algebraically from *that between 5° and 35°* by more than 0.30 second.

(11) The *mean daily rate of any of the 15 periods* (except period 11) not to exceed 10.0 seconds.

8. Application of Tolerances. — In determining whether a watch's performance is within the above tolerances the various quantities shall be computed as follows:

(1) To obtain the *mean deviation of daily rate* the difference between each day's rate and the mean daily rate of the period in which it occurs shall be taken for all periods except the eleventh, and the arithmetical mean of the 48 differences thus obtained shall be taken as the mean deviation of daily rate.

(2) To obtain the *mean deviation for change of position*, the algebraic average shall be taken of the mean daily rates of periods 1 and 10, 2 and 9, 3 and 8, 4 and 7, and 5 and 6, and from the algebraic mean of the five values corresponding to the five positions obtained in this way each of the five shall be subtracted. The arithmetical mean of these five differences shall be taken at the *mean deviation for change of position.*

(3) The five mean rates thus obtained for the five positions shall be used in applying the third. fourth, and fifth tolerances, the differences being taken algebraically.

(4) To obtain the *progressive change in rate in periods 1 to 10*, the difference between the mean rates of periods 1 and 10, 2 and 9, 3 and 8, 4 and 7, and 5 and 6

* This period to be an isochronism test, readings being made at intervals of a few hours from the time of winding the watches at the beginning of the period until they run down.

shall be taken and the algebraical mean of the five values so obtained shall be taken as the mean recovery of rate in periods 1 to 10 and will represent the average change in rate of the watch in 15 days. The differences shall be so taken that a plus sign shall indicate that the watch ran slower at the end of 15 days than at the beginning; a minus sign that it ran faster.

(5) The *recovery of rate*, period 15 minus period 1, shall be taken with the same meaning of plus and minus signs as above.

(6) To obtain the *isochronism error*, twice the amount gained or lost in the first 12 hours of the isochronism test of period 11 shall be subtracted algebraically from the amount gained or lost in the first 24 hours of this test. This algebraic difference shall be taken as the *isochronism error*, and a minus sign will indicate that the watch ran at a faster rate in the first 24 hours after winding than in the first 12 hours, a plus sign that it ran slower.

(7) The *difference of rate per degree centigrade* shall be obtained from the results of the three temperature periods by the solution of the three equations of the form $r = r_{20} + a(t - 20) + b(t - 20)^2$ where r is the observed rate at $t°$ C, and r_{20} is the rate at 20° C (to be determined) and a and b are two constants to be determined From these results the rates at 5° and 35° are also found (if not already observed) and the algebraic differences of the rates at 5°, 20°, and 35° C are divided by the differences of temperature to obtain the *difference of rate per degree centigrade*.

9. Certificates. — The certificate granted under regulation 7 will show the mean daily rate of the watch in each of the 15 periods, except period 11, and the mean temperature at which the watch ran in each period. It will also show the various quantities computed for the different criteria of regulation 7, together with the tolerances for the same. The results of the isochronism test will be given in the form of a curve accompanying the certificate and showing the amounts gained or lost after winding. The certificate will also give the maker of the watch, if known, and the maker's number of the watch, together with such additional details of description as may seem desirable. The name of the person by whom or for whom the watch was submitted for test will be given. The certificate will be dated according to the last day of the test. The certificate will bear the signature of the Director of the Bureau of Standards (or of the Acting Director of the Bureau in case of absence of the Director) and will be stamped with the seal of the Bureau of Standards. The certificate will also give a number to indicate the relative performance of the watch based on a scale from 0 to 100, as provided in regulation 10, in which 0 indicates a watch that has just met the limits of tolerances 1, 2, 7, 9, and 10, and 100 indicates a watch whose performance would be perfect with respect to these factors.

10. Relative Performance. — On each watch certificate under class A will be given its relative performance on a scale from 0 to 100, computed according to the following formula:

$$\text{Relative performance} = 30\left(1 - \frac{a}{0.75}\right) + 30\left(1 - \frac{b}{3.00}\right) + 30\left(1 - \frac{c}{0.25}\right) + 10\left(1 - \frac{d}{6.0}\right).$$

Where a = the observed *mean deviation of daily rate*.

b = the observed *mean deviation for change of position*.

c = the arithmetical mean of the *difference of rate per degree centrigrade between 5° and 35°* and the amount by which the *difference of rate per degree centigrade between 5° and 20°* differs algebraically from the *difference of rate per degree centigrade between 5° and 35°*.

d = the *recovery of rate* (period 15 minus period 1).

When a watch receives a relative performance of 75 or more it will be noted on the certificate as "very satisfactory."

11. Reports on Rejected Watches. — The test of a watch which fails to meet the requirements of class A at any point in the test will be continued to the end (except in case of the accidental stopping of the watch or its withdrawal from test by the person submitting it), and a report will be made showing the results of the test and giving the items under which it was rejected. If the watch has stopped during the test from accidental or unexpected causes, or if it is withdrawn from test before the completion of the test, a report will be made of the rates of the watch for as much of the test as it underwent. A watch may be withdrawn from test at any time during the test by the person submitting it or may be withdrawn before period 11 by request made in the application for the test in case the watch fails to meet the requirements of tolerances 2, 3, 4, 5, 6, and 11 (the latter as applied to periods 1 to 10 only). In case a watch stops from accidental or unexpected causes or is withdrawn from test before the eleventh period, only half the fee for a complete test will be charged.

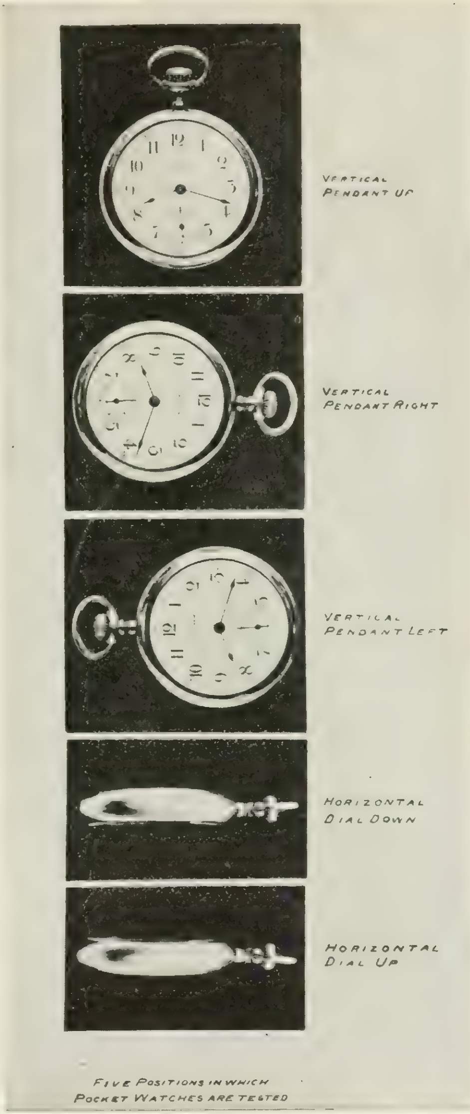


Fig. 305. — The five positions in which a watch is tested at the Bureau of Standards.

The fee for Class A tests is $5 and for Class B tests, $3. In Fig. 305 are shown the five positions in which a pocket watch is tested. Fig. 306 pictures the cabinet

in which the watches are placed during the tests. An "overflow case," made necessary by the large number of

FIG. 306.—THE CABINET IN WHICH THE WATCHES ARE PLACED FOR TESTS. (Bureau of Standards, Washington, D. C.)

watches submitted, is shown at the right. Fig. 307 shows the cabinet open. The coils at the top are for the circulation of brine to maintain the desired temperatures.

In general, then, as a summary, it may be stated that the testing of a watch at the Bureau of Standards in Washington or at the foreign observatories where watches are

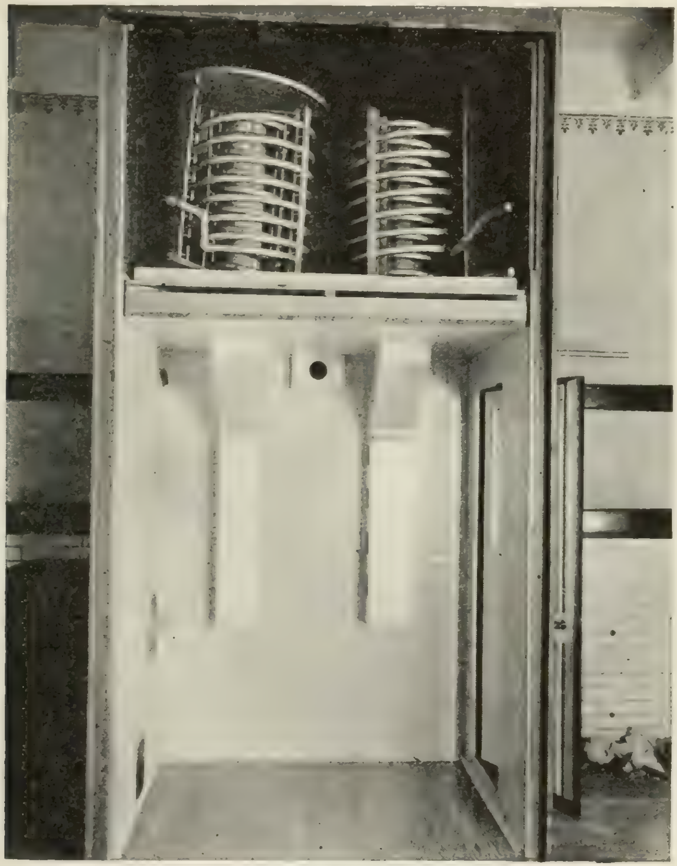


FIG. 307. — THE CABINET OPENED.
(Bureau of Standards, Washington, D. C.)

tested, consists in observing the rate while the watch is running in different positions and at different temperatures. The isochronism curve and the recovery of rate after being subjected to different conditions are also usually deter-

mined. The tolerance limits and the formulas used for computing relative merit are different at different places but all are very much alike. It is really the three adjustments of a watch to temperature, position, and isochronism that are tested.

CHAPTER XXV

SOME FAMOUS CLOCKS AND WATCHES

Most timekeepers have no individuality. They carry a factory number which is only looked up when they are lost or is carefully recorded by the jeweler who cleans and repairs them. Their peculiarities and eccentricities are known only to their owners or a small circle of acquaintances. A few timekeepers, however, have gained sufficient fame to be known individually to all who are interested in time and timekeepers. It is to these that the present chapter is dedicated.

There is a variety of ways in which a timekeeper may gain extended fame and become individually known. It may be very old. It may be unusually large for its kind. It may be particularly elaborate and intricate. It may have been the first to embody some new idea. Perhaps it is of very small size. It may have been the masterpiece of some well-known maker. Perhaps the one who owned and used it was some very famous person. Thus for varied reasons a timekeeper may have gained name and fame.

In taking up clocks and watches which have become famous it will be convenient and useful to divide them into groups and then to consider the most famous ones in each group. These groups are: (1) Clocks constructed before 1360, as all of these are worthy of individual attention; (2) the large intricate clocks placed in or on cathedrals and public buildings; (3) smaller intricate clocks which were sometimes copies of the cathedral clocks and often made for exhibition purposes; (4) modern tower clocks; (5) precision clocks; (6) domestic clocks; (7) chronometers; (8) watches.

Clocks constructed before 1360. — It is intended to include under this head only mechanical clocks, that is,

clocks consisting of an assemblage of wheels and actuated by a weight and not clepsydras or water clocks of any kind. The number of clocks constructed before 1360 was not large. There were probably more than twenty and less than a hundred. It is impossible to state the exact number. An obscure writer often mentions a clock as existing in a certain town at a certain early date. He may be recording only hearsay and thus mistaken. It may have been only a clepsydra. It may have been of a much more recent date. By 1600 practically every city and town possessed a public clock of greater or less pretensions. Thus it is impossible to state with accuracy the exact number of mechanical clocks constructed before 1360. They were all ponderous clocks, either tower clocks or large clocks to be placed in or on cathedrals or public buildings. At first they were of fairly simple construction, keeping time, striking the hours, and perhaps sounding an alarm at certain times. Just before 1360 they sometimes were more intricate, having a perpetual calendar and automatic figures which enacted scenes.

All of these early clocks have been mentioned and sufficiently described in Chapter IV on "The History of Clocks to 1360" and Chapter VI on "The History of Clocks from 1360 to 1500." The most famous of them all is without doubt the clock constructed by Henry De Vick of Würtemberg for Charles V of France. It was placed on the round tower of the Palace, which is now the Palais de Justice in Paris. It has been pictured and fully described in the chapters just mentioned. The next six which are best known are perhaps the following: St. Paul's in London, 1286; Westminster in London, 1288; Exeter Cathedral clock, 1317; Wells Cathedral clock, 1325; Strasbourg, 1352; Nürnberg, 1356. In the case of St. Paul's clock, the Westminster clock, and the Strasbourg clock, later successors have been far more famous than the original clocks.

Cathedral clocks. — The large intricate clocks which were placed in or on cathedrals, city halls, and other public buildings began to be constructed between 1300 and 1400.

By 1600 nearly every city or large town had a pretentious public clock. The crest of the wave of popularity passed then and since that time the number constructed has rapidly and steadily declined. Some of them were very elaborate. They not only indicated the various kinds of time, but had a perpetual calendar, showed the motions of the heavenly bodies, and had many automatons which enacted various scenes.

If one were to consult the various books and articles which have been written about these clocks, it would be found that the following list contains practically all the clocks to which reference is ever made.

Amiens
Augsburg, 1398
Auxerre, 1372
Bâle
Beauvais, 14th century
Berne, 1530
Besançon, 1860
Bologna, 1356
Breslau, 1368
Brussels, 16th century
Caen, 1314
Calais, 16th century
Cambrai, 1385
Canterbury, 1292
Chambrey, 1376
Chartres, 16th century
Cluny, 1340
Coblentz, 16th century
Colmar, 1370
Cologne, 1385
Compiègne, 1405
Courtrai, 1382
Danzig, 1470
Dijon, 1383
Dover Castle, 1348
Durham, 1648
Exeter (Cathedral clock), 1318
Exeter (St. Mary of Ottery), 1340
Frankfort, 1605
Genoa, 1353
Glastonbury Abbey
Hampton Court Palace (London), 1540
Heilbronn, 1580
Jena, 16th century
Lille, 1378
Linden
Lübeck, 1405
Lund, 14th century
Lyons, 1598
Magdeburg, 1425 (perhaps 1396)
Mainz, 1369
Metz, 1391
Montargis, 1380
Montélimart
Montpellier
Moscow, 1404
Munich, 15th century
Niort, 1570
Norwich, 1323
Nürnberg, 1356
Olmütz, 1420
Oxford (St. Mary's), 1469
Padua, 1344
Paris (De Vick's), 1360
Pavia

Peterborough, 1320
Prague, 1419
Ratisbon
Riom
Rouen, 1389
Rye
St. Albans, 1326
St. Dunstan's (London), 1671
St. Paul's (London), 1286
Senlis
Sens, 1377
Seville, 1401
Southwold
Spires, 1395
Strasbourg, 1352
Troyes, 1379
Ulm, 1549
Venice, 1495
Wells, 1325
Westminster (London), 1288
Wimborne, 1320
York, late 15th century

The dates are sometimes somewhat uncertain and are occasionally given differently by different writers. These clocks have in nearly all instances been reconstructed and renovated and it is often a later successor which is more famous than the original clock. Sometimes the clock no longer exists or has been placed in some museum.

If one were to choose the twenty-five best known from this list they would perhaps be the clocks at the following places.

Beauvais, 14th century
Berne, 1530
Dijon, 1383
Exeter (Cathedral), 1318
Exeter (St. Mary of Ottery), 1340
Hampton Court Palace (London), 1540
Jena, 16th century
Lübeck, 1405
Lyons, 1598
Metz, 1391
Norwich, 1323
Nürnberg, 1356
Olmütz, 1420
Padua, 1344
Paris (De Vick's), 1360
Peterborough, 1320
Prague, 1419
Rouen, 1389
St. Dunstan's (London), 1671
St. Paul's (London), 1286
Strasbourg, 1352
Venice, 1495
Wells, 1325
Westminster (London), 1288
Wimborne, 1320

Of these, the clocks at Dijon, Exeter, Norwich, Nürnberg, Padua, Paris (De Vick's), Peterborough, St. Paul's (London), Wells, Westminster, Wimborne, have already been treated in Chapter IV on "The History of Clocks to

1360." The four clocks at Lyons, Prague, Strasbourg, and Venice are reserved at present for a more detailed treatment later. This leaves the clocks at Beauvais, Berne, Hampton Court Palace (London), Jena, Lübeck, Metz, Olmütz, Rouen, and St. Dunstan's (London) for immediate consideration.

Beauvais Cathedral Clock

The cathedral at Beauvais in northern France is famous for its clocks. In Fig. 308 is shown the present appearance of an old fourteenth-century clock. It now has two hands and looks quite modern. There is also a large modern monumental clock which will be mentioned later (page 507).

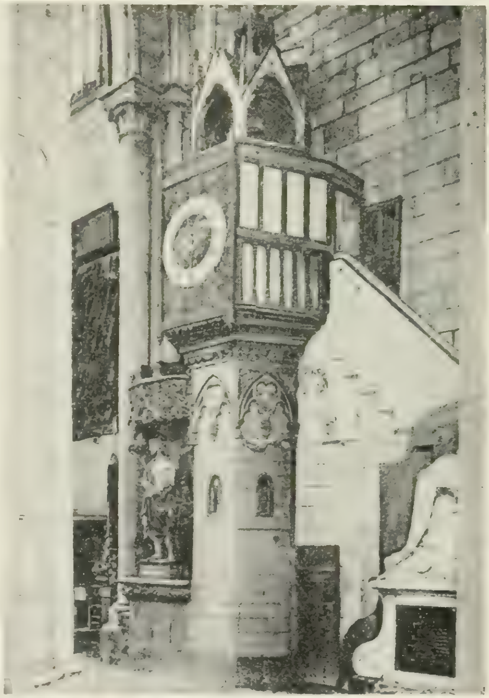


FIG. 308. — A FOURTEENTH-CENTURY CLOCK IN BEAUVAIS CATHEDRAL.

Berne Clock

The famous Berne clock is located on the eastern side of La Tour de l'Horloge (Zeitglockenthurm) which was the western gate in the early days of the city but is now not far from the center. It was constructed by Gaspard Brunner and dates from about the middle of the sixteenth century. At present it consists of four parts. At the very top of the tower are the jacks for striking the hours on the bells there.

Below is the large dial on which are indicated the hour and minute. Below this is the smaller, older dial on which is indicated not only the time but the calendar as well. To

FIG. 309. — THE FAMOUS OLD CLOCK AT BERNE.
(Photo., Underwood & Underwood, London.)

the right of this and on the same level are the moving figures. The cock (left) crows as the hour approaches and the bear (right) turns its head as each stroke of the hour is

sounded. In the center is the figure of an old man or elf who strikes the quarters on small bells near him. Each hour a troop of men and bears marches around this central figure. It will be remembered that the bear is the heraldic emblem of Berne. This clock is pictured in Fig. 309.

Hampton Court Palace Clock

At Hampton Court Palace, over the gateway in the second quadrangle of that portion of the building which was erected by Cardinal Wolsey, facing the east, were the dial and works of an elaborate clock, which carried the engraved initials of the maker, N. O. or N. C., and the date 1540. If the letters were N. C., then Nicholas Cratzer may have been the maker. In 1575 a payment was made to George Gaver "for painting the great dial at Hampton Court, containing the howres of the day and night, the course of the sonne and mone, the xij signes with the characters of the vij planetes, environed into a circle, the sea, shippes, and territories; and on the other side certain badges of the croune, all wrought in oil colours, as vemilion, &c., and guilded with fine goulde; for clensinge the sconde diall contg. the howers of the daie, half-howers and quarters, and in divers places her mat[s] trio of name, and sondrie her mat[s] badges, wrought likewise in oyle colours and guilded with fine goulde." During the last half of the eighteenth century the statement was sometimes made that the clock had been constructed by Tompion. This is evidently a mistake, as he was not born until 1638. Probably he had repaired or renovated the clock. The clock had been repaired by Langley Bradley in 1711 and was again repaired and altered between 1760 and 1800. In 1835 the movement and dial were taken down and replaced by another clock bearing the inscription: "This clock, originally made for the Queen's Palace in St. James' Palace and for many years in use there, was, A.D. 1835, by command of his Majesty King William IV, altered and adapted to suit Hampton Court Palace by B. L. Vulliamy, clockmaker to the king." The works of the original clock have disappeared. In 1879 the old dial was found and replaced and a new move-

ment was provided by Mr. James Thwaites. It now probably indicates the time and the various astronomical events more exactly than in the beginning, but there is really nothing left of the old clock but the dial. An excellent

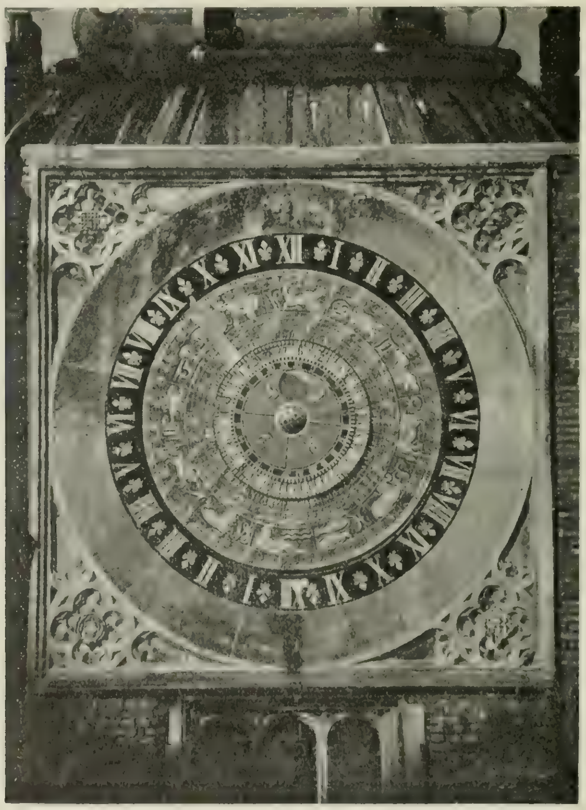


FIG. 310.—THE HAMPTON COURT PALACE CLOCK.

photograph of this dial is reproduced by the kind permission of the Lord Chamberlain as Fig. 310.

The dial at present consists of three separate copper discs which revolve and three pointers, a little arrow, a triangle, and an arm carrying the sun. In the center is a

slightly raised globe representing the earth. The spaces numbered 1, 2, 3, and 4 are for indicating the quarter in which the moon is. The circular opening is 10 inches in diameter and behind this a revolving disc shows the varying appearance of the moon. The next circle is divided into 24 hours and its purpose is to indicate when the moon souths, i.e., crosses the meridian. The little arrow points out the hour and the quarter of the moon. The next circle is to indicate the moon's age and this is done by the triangular pointer. The next circles in order indicate the month, the day of the month, the sign of the zodiac in which the sun is located, and the degree of the sign. The arm carrying the sun points these out. The 24 hours are painted on the stonework within which the dial revolves. This outer circle is about 10 feet in diameter. In the figure (reading from the outside in) it is 9:30 A.M.; the sun is in the 30th degree of Virgo; it is the 20th of September; it is the 26th day of the moon's age; the moon souths at 9 A.M., and is in the fourth quarter.

FIG. 311. — THE "HANS VON JENA" CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

JENA CLOCK

This clock, usually called the "Hans von Jena" clock, was constructed about the middle of the 16th century by an unknown maker. Above the dial, as shown in Fig. 311, is a large bronze head with wide-open mouth. As the hour is struck, the pilgrim on the left presents a golden apple to the open mouth, but quickly withdraws it

before the mouth can be closed. The angel on the left raises its eyes and shakes the small bell as each blow of the hour is struck.

Lübeck Clock

This clock was constructed in 1405 and is located in the church of St. Mary at the back of the high altar. This

FIG. 312. THE LÜBECK CLOCK.

church is an admirable example of low-German brick architecture. The clock is still going but was repaired in

1860 and 1889. It shows the motions of the heavenly bodies and when it strikes twelve, a number of automaton figures are set in motion. The Electors of Germany enter from a small side-door, and perform the ceremony of inaugurating the Emperor, who is seated upon a throne in front. Another door is then opened and Christ appears, when, after receiving his benediction, the whole cavalcade retires amidst a flourish of trumpets by a choir of angels. The present appearance of this clock is shown in Fig. 312.

Metz Clock

The clock at the Cathedral in Metz is an old one, for it dates from 1391. Its original place in the cathedral is unknown, but in 1510 it was placed in the east turret of the edifice and presumably renovated and perhaps remodeled. It struck the hours and quarters and showed the course of the sun and the phases of the moon.

Olmütz Clock

The Olmütz clock was constructed in 1420 by Anton Pohl of Saxony. A traveler in 1560 described it as a true marvel, rivaling the clock at Strasbourg. Later it was neglected and many parts were stolen. Recently (1898) it was renovated by Korfhagen. In fact it is practically a new construction. It is located on the city hall of this important city of Moravia, Austria, now Czechoslovakia. It is elaborate and artistic, having many dials and moving figures. Its present appearance is shown in Fig. 313.

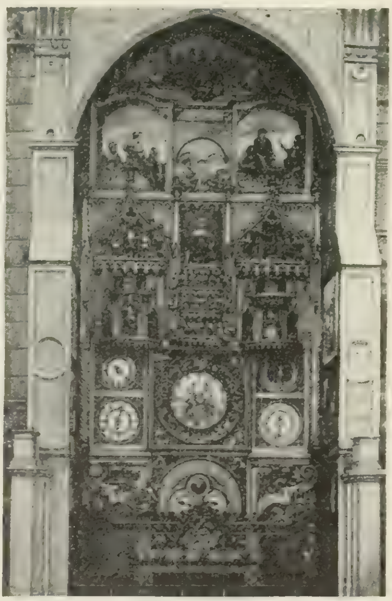


FIG. 313.—THE OLMÜTZ CLOCK.

The Clock at Rouen

The clock at Rouen is placed over a round arched gateway which is surmounted by a tower and spans the Rue de la Grosse Horloge. This is probably not the original location of the clock, as it was constructed in 1389 by Jehan de

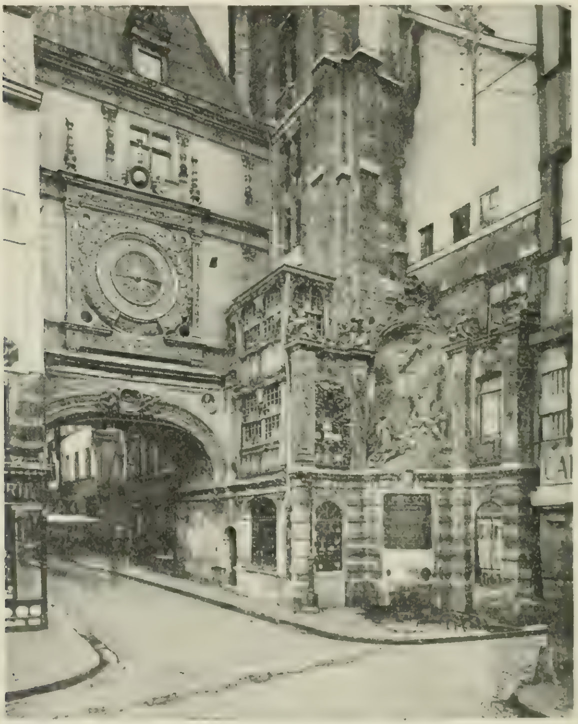


FIG. 314. - THE CLOCK AT ROUEN.

Féalins, and the arch was completed in 1527. The clock has a dial about 6 feet square and only one hand. It indicated the time, day of the week, and phases of the moon. It is essentially in its original condition, although there have been some modern alterations in the movement. It is pictured in Fig. 314.

St. Dunstan's Clock at London

This remarkable clock was placed on St. Dunstan's Church in Fleet Street, London. It projected over the street and was set up in 1671. Its maker was Thomas Harrys, a clockmaker, then living at Water Lane, Blackfriars. It replaced an older clock, but about that practically nothing is known, although there are vague references to a clock in Fleet Street running back nearly two centuries earlier. The clock had a square ornamental case, a large gilt dial, on either side, and a semicircular pediment. The tube from the church to the dial was supported by a carved figure of Time, with expanded wings. Above it in an alcove, in a standing posture, were two life-size wooden figures of savages or Hercules with clubs in their right hands, who struck the quarters on the two suspended bells between them. The figures seem to have been one of the sights of London. The church was taken down in 1831. The clock and figures were purchased by the Marquis of Hertford and removed to his villa in Regent's Park. The purchase price is said to have been 210£.

Modern Intricate Clocks at Beauvais and Besançon

At both Beauvais and Besançon there is a large modern, intricate, monumental clock. These two have been mentioned together because they were both constructed by the same man, namely, by M. Vérité, a skillful clockmaker of Beauvais.

At Beauvais the clock is located in the left choir chapel of the cathedral. It has many dials, indicating different things, a crowing cock, and automatons which enact scenes. It is 39 feet high, 20 feet broad, 9 feet deep, and is said to be composed of 90,000 pieces.

At Besançon, the clock is located in the Cathedral of Saint-Jean. It was finished in 1860 at a cost of 180,000 francs. In 1900 it was repaired and reconstructed by M. Florian Goudey of Besançon. The clock has 70 dials which

give 122 indications and consists of about 30,000 pieces. It is also provided with moving scenes and automatons.

These modern clocks keep much better time and are fully as elaborate and intricate as the older cathedral clocks. They lack, however, the charm of the antique.

Four very elaborate and well-known clocks which are still doing their duty at the present time have been chosen for a more detailed description. These are the clocks at Lyons, Prague, Strasbourg, and Venice.

The Lyons Clock

In the north transept of the Cathedral of St. John, at Lyons, France, stands the famous clock. It is in the form of a tower and about forty feet high. It is usually stated that it was contrived by Nicolas Lipp (or Lippius to use the Latin form of his name) of Basle and finished in 1598. Jacques Levet, a clockmaker of Lyons, also had a part in the work. There is this statement, however, dating from 1572: "It did not run any more." This would seem to indicate that the clock was much older than 1598 and that Lipp had simply renovated it or replaced the older clock with a new one. It was repaired and improved by Guillaume Nourrisson, a skillful local clockmaker, in 1661, and it is his name which appears on the tablet at the base of the clock. He added, among other things, the oval dial with the hand which changes in length. The clock was renovated for the last time in 1895, when it was thoroughly repaired by M. Vaudremer of Chateau Frères & Cie, of Paris, by direction of the French Government. Attempts at repairs had also been made several times between the time of Nourrisson and 1895 but always with indifferent results. The most extensive were by Pierre Charmy in 1780. It is to be noted that these repairs left the mechanism as it was. Thus the Lyons clock, both as regards case and movement, is really old. There is a tradition that Lipp, after finishing the clock, had his eyes put out so that he would never be able to make another clock like it. Far from this being a fact, Lipp was

FIG. 315. — AN OLD VIEW OF THE LYONS CATHEDRAL CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

loaded with honors and engaged to take care of his own clock at a handsome salary until his death. The first of the two illustrations (Fig. 315) is taken from the magnificent work *Histoire de l'Horlogerie* by Pierre Dubois and dates from about 70 years ago. The second illustration (Fig. 316) is modern.

The clock consists of three parts, the lower story, the middle story, and the automatic figures at the top. At the left of the lower story is the door which gives access to the movement. On the front is the dial which indicates among other things the day of the year, the month, the day of the month, and the daily letter. A small board indicates the date of Easter and the like. This ecclesiastical calendar is good for 66 years, from 1894 to 1960. On the left has been placed the old calendar which ran from 1782 to 1848.

On the right of the middle story is the large oval dial for indicating the minutes, which was added by Nourrisson. The single hand dilates and contracts five inches in passing around the dial so as to always reach the periphery. On the front is the dial for indicating the hour of the day, the position of the sun, and the phases of the moon. On the left of this story there is an inscription.

The upper part of the clock is reserved for the automatic figures. The day of the week is indicated by means of a figure which appears in a gilt niche at midnight and remains in place until the next midnight. For Sunday the figure symbolizes the Resurrection; Monday, Death; Tuesday, St. John; Wednesday, St. Stephen; Thursday, The Sacrament; Friday, The Passion; Saturday, The Virgin. On the left of the figure which indicates the day of the week there is an angel which turns a sand-glass. On the right another angel with a baton beats in unison with head, hand, and feet as the clock strikes. Above these is the figure of a Virgin kneeling. Above this is a representation of God the Father backed by angels with bells. Above this is a gallery and the whole is surmounted by a cock.

The clock strikes five times a day; at five and six in the

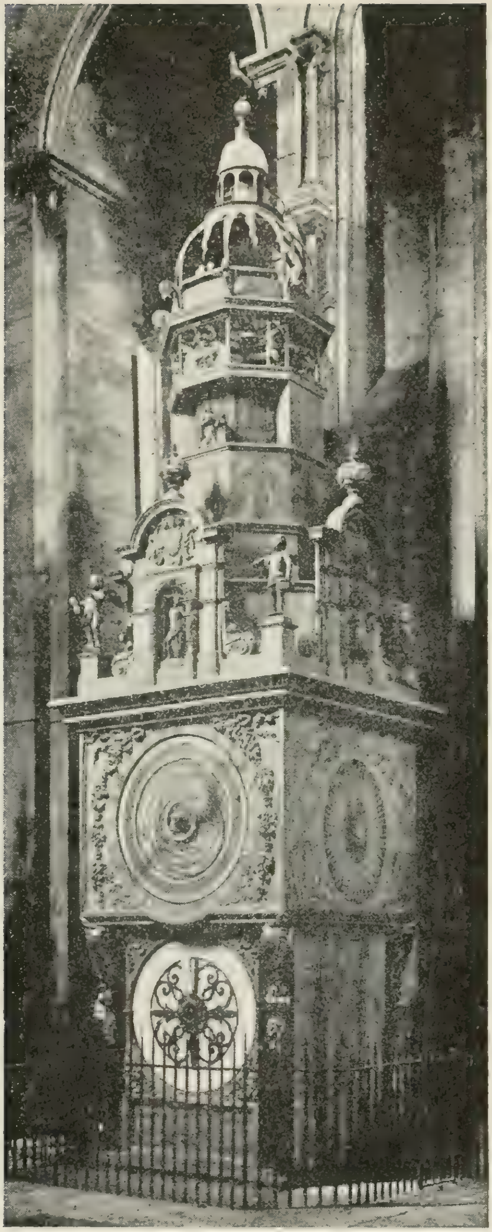


FIG. 316. — THE FAMOUS CLOCK IN THE CATHEDRAL AT LYONS.

morning, at noon, and at one and two in the afternoon. When the striking time arrives, the angel at the left turns the sand-glass. The cock then crows three times, stretching out its neck and flapping its wings. The angels then play upon the bells the hymn of John the Baptist: "Ut queant laxis," while the lower angel at the right beats time. A door now opens and the angel Gabriel appears before the Virgin. The ceiling opens and a dove descends. God the Father gives his blessing. The figure of a beadle now appears and marches around the upper gallery. All the moving figures then withdraw and the hour is struck on a bell at the top just below the cock.

The Clock at Prague

The famous clock at Prague (Fig. 317) is located on the Rathaus or City Hall in the Altstadt portion of the city. Some say that it was constructed by Anton Pohl of Saxony in 1419. Others claim that it was erected by Hanusch, a local clockmaker, in 1490. It is in running order at present, although for long series of years large portions of the movement were out of order. There are two large dials. The lower one is a perpetual calendar and the upper one shows the motions of the sun and moon. Each time, just before the hour is struck, two square windows above the dials are pushed aside and the twelve Apostles pass the windows. The figure of Death, which stands at the right of the upper dial, rings a bell before the hour is struck and turns over an hour-glass. The man standing near nods with his head. On the other side of this dial are two figures: one a miser with a purse and another with a mirror typifying vanity. After the clock has struck the hour, a cock appears at the top and crows three times.

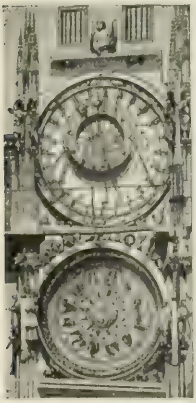


FIG. 317. THE CLOCK ON THE CITY HALL OF PRAGUE.

The Strasbourg Clock

The astronomical clock in the cathedral at Strasbourg in Alsace is without doubt the most famous clock in the world. It is always spoken of as *the* astronomical clock, although as a matter of fact there have been three distinct clocks.

The first clock dates from 1352. It was begun under Bishop Berthold von Bucheck and finished two years later under Bishop Johann von Lichtenberg. It was placed on the Western wall of the South Transept opposite the present clock. Its corner stones projecting from the wall may still be seen. It consisted of a perpetual calendar, an astrolabe, figures of the three wise men and the Virgin carved in wood, and a cock. At the stroke of each hour the Magi bowed before the Virgin and the cock crowed and flapped its wings. There was also a small set of chimes. By 1500 this clock was totally out of order and had ceased to work. At present there is nothing left of it except possibly a few wheels and parts of the cock.

In 1547 the magistrate of the free imperial city of Strasbourg ruled that a new astronomical clock should be constructed. The task was intrusted to three mathematicians: Michel Herr (or Heer), Christian Herlin, and Nicholas Prugner (or Bruckner). They set to work at once but left it unfinished. In 1570 Conrad Dasypodius, professor of Mathematics at Strasbourg, and David Walkenstein (or Volkenstein) undertook the completion of the clock. The mechanical execution was entrusted to Isaac and Josiah Habrecht of Schaffhausen and Tobias Stimmer (or Sturmer), an artist. In the meantime Josiah Habrecht was summoned to Cologne for other work and Isaac Habrecht was left alone to finish the movement, which he did in 1574. The price agreed upon was 7000 florins in addition to food and lodging. Considering the value of the florin and the worth of money at that time, this was a big sum, equivalent to nearly 200,000 francs at present. The framework and paintings were done by Stimmer. Fig. 318 is from an old cut of the clock which appeared in Dubois' excellent work,

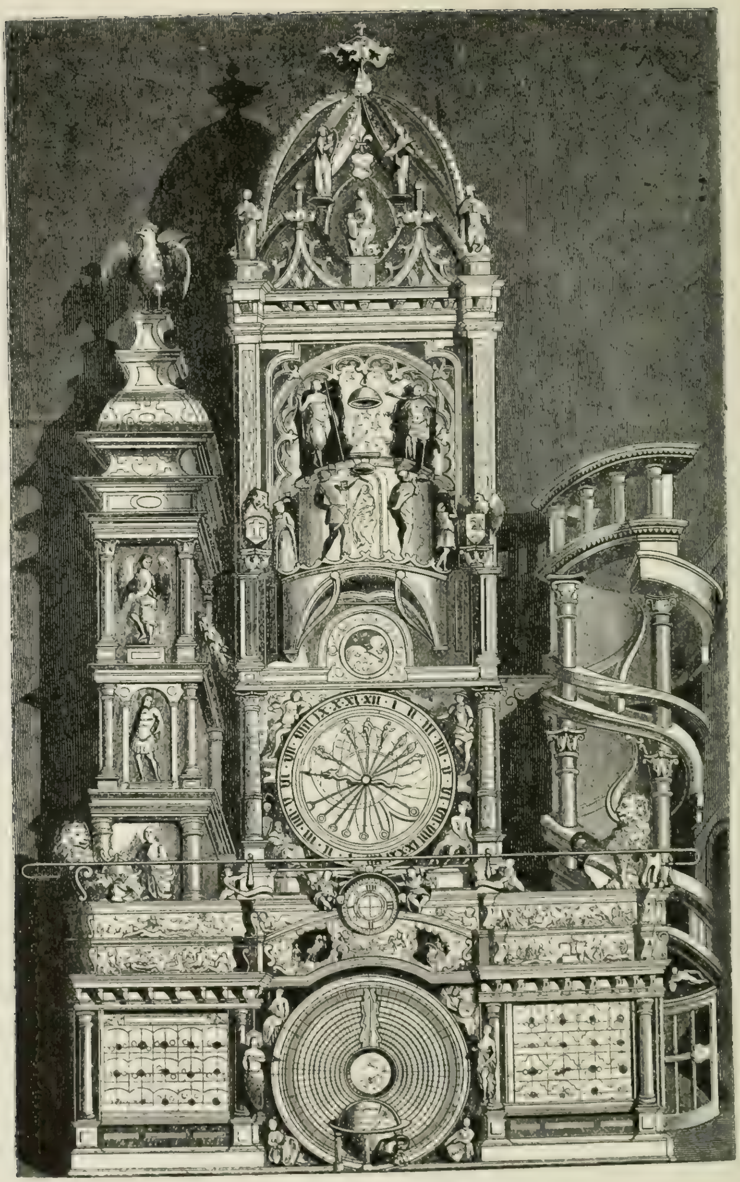


FIG. 318. — THE SECOND STRASBOURG CLOCK.

(From DUBOIS, *Histoire de l'Horlogerie.*)

Histoire de l'Horlogerie, more than seventy years ago. An old description, which is also quoted in Wood's very interesting book, *Curiosities of Clocks and Watches*, runs as follows:

"Herein nine things are to be considered, whereof eight are in the wall; the ninth (and that the most wonderful) stands on the ground three feet from the wall. This is a great globe of the heavens, perfectly described, in which are three motions: one, of the great globe, which displays the whole heavens, and moves about from the east to the west in twenty-four hours; the second is of the sun which runs through the signs there described once every year; the third is of the moon, which runs her course in twenty-eight days. So that in this globe you may view the motions of the whole heavens, the motions of the sun and moon, every minute of an hour, the rising and falling of every star (amongst which stars are the makers of this work, Dassipodius and Wolkinstenius) described. The instruments of these motions are hid in the body of a pelican, which is portraited under the globe. The pole is lifted up to the elevation of Strasbourg, and noted by a fair star made of brass; the zenith is declared by an angel placed in the midst of the meridian. The second thing to be observed (which is the first on the wall) are two great circles, one within another, the one eight feet, the other nine feet broad; the outmost moves from the north to the south once in a year, and hath two angels, one on the north side, which points everyday in the week; the other on the south side, which points what day shall be one-half year after. The inner circle moves from south to north once in a hundred years, and hath many things described about it; as the year of the world, the year of our Lord, the circle of the sun, the progressions of equinoctials, with the change of the celestial points, which things fall out by the motions which are called trepidations; the leap-year, the movable feasts, and the dominical letter, or golden number, as it turns every year. There is an immovable index, which incloses for every year all these things within it; the lower part of which index is joined to another round circle which is immovable, wherein the province of Alsatia is fairly described, and the city of Strasbourg. On both sides of the circles, on the wall, the eclipses of the sun and moon are, which are to come for many years, even so many as the wall might contain. The third thing, a little above this, is a weekly motion of the planets, as they name the day; as on Sunday, the sun is drawn about in his chariot, accordingly as the day is spent;

and so drawn into another place, that before he be full in, you have Monday; that is the moon clear forth, and the horses of Mars' chariot putting forth their heads; and so it is for every day in the week. On this side there are nothing but dumb pictures to garnish the wall. The fourth thing is a dial for the minutes of the hour, so that you see every minute pass. Two beautiful pictures of two children are joined to either side of this; he on the north side hath a sceptre in his hand, and when the clock strikes, he orderly tells every stroke; he on the south side hath an hour-glass in his hand, which runs just with the clock, and when the clock hath struck, he turns his glass. The first thing above the minute-dial is a dial for the hour, containing the half-parts also; the outermost circumference contains the hours; but within it is a curious and perfect astrolabe, whereby is shown the motion of every planet, his aspect, and in what sign, what degree, and what hour, every one is in every hour of the day; the opposition likewise of the sun and moon, and the head and tail of the dragon. And because the night darkens not the sun, nor the day the moon, or other planets, therefore their courses are here exactly seen at all times. The sixth thing is a circle, wherein are two signs of the moon's rising and falling; at two hollow places it is seen at what state she is; and her age is declared by an index, which is wholly turned about once in every month. The seventh thing consists of four little bells, whereon the quarters of the hour are struck; at the first quarter comes forth a little boy, and strikes the first bell with an apple, and so goes and stays at the fourth bell until the next quarter; then comes a lusty youth, and he with a dart strikes two bells, and succeeds to the place of the child; at the third comes forth a man-in-arms, with a halbert in his hand, and strikes three bells; he succeeds into the place of the youth; at the fourth quarter, comes an old man with a staff, having a crook at the end; and he with much ado, being old, strikes the four bells, and stands at the fourth quarter, until the next quarter; immediately to strike the clock comes Death in a room above the others, for this is the eighth thing; and this, understand, that at each quarter he comes forth to catch each of those former ages away with him; but at the contrary side, in the same room where he is, comes forth Christ and drives him in; but when the last quarter is heard, Christ gives him leave to go to the bell, which is in the midst, and so he strikes with his bone, according to the hour; and he stands at the bell, as the old man

doth at his quarter-bell, till the next quarter, and then they go in both together. The ninth and last thing in this right line is the tower at the top of the work, wherein is a noble, pleasant chime, which goes at three, seven, and eleven o'clock, each time a different tune; and at Christmas, Easter, and Whitsuntide, a thanksgiving unto Christ; and when the chime has done, the cock (which stands on the top of the tower, and the north side of the main work), having stretched out his neck, shook his comb, and clapped his wings twice, crows twice, and this he does so shrill and naturally, as would make any man wonder; and if they choose who attend the clock, they can make him crow more times. In this tower are conveyed all the instruments of these motions, which are in the aforesaid things."

FIG. 319.—SCHWILGUÉ, WHO CONSTRUCTED THE THIRD ASTRONOMICAL CLOCK AT STRASBOURG.

In one or more of the years 1625, 1630, and 1640, for the dates are variously given, the clock was struck by lightning. When finally repaired the cock was made to crow only on Sundays and feast days. In 1789 the cock ceased to crow entirely and in 1818 there is a record that the clock was then totally out of order.

In 1836 it was decided that a new astronomical clock should be placed in the framework of the old one. The construction of this third clock was entrusted to Jean Baptiste Schwilgué, who commenced work in 1838 and finished it in 1842. Schwilgué was born in Strasbourg in 1774 and from a boy showed great interest in mechanical things. His picture as given on the lower left-hand panel is reproduced as Fig. 319. The clock when finished cost 101,725 francs.

The clock was formally set in motion on October 2, 1842. Fig. 320 is from a modern photograph. The pres-

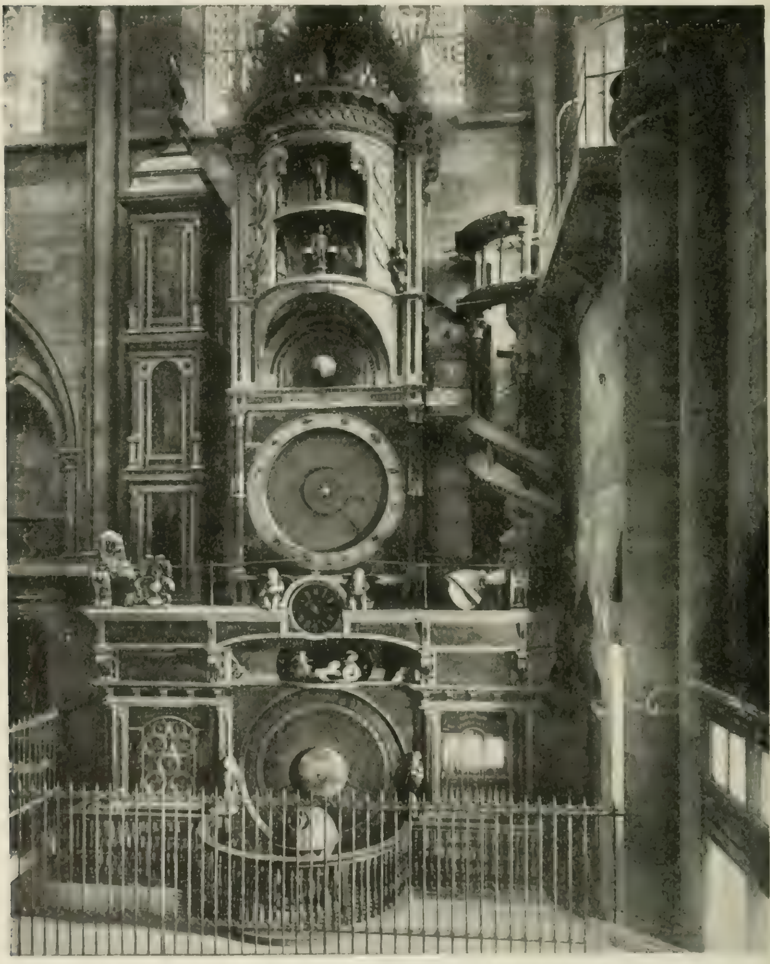


FIG. 320. – THE FAMOUS STRASBOURG CATHEDRAL CLOCK.

ent clock is about 30 feet high and 15 feet wide at the base. On the right side there is a flight of winding steps which gives access to the various galleries of the clock.

On the left side there is a Gothic pillar which contains the weights and is surmounted by the historic cock as in all the other clocks. The panels consist of figure paintings, Urania, Copernicus, and Schwilgué from the top down. Below in front of the clock there is a globe about three feet in diameter representing the celestial sphere. All stars to about the sixth magnitude, that is, all visible to the unaided eye, are represented. This globe turns so as to indicate the sidereal time and the time of the rising and the setting of the stars. Behind the globe is the calendar dial which shows the date, and the fixed and movable feasts, including *Easter*. This calendar changes automatically at midnight on December 31, so as to show the proper indications for the coming year. In the middle of this dial are indicated the true solar time, the time of rising and setting of the sun and moon, and eclipses. On the left of this calendar dial other chronological letters and cycles are indicated, namely, from the top down, the year, the solar cycle, the golden number, the indication, the dominical letter, and the epact. At the right the equation of time and similar quantities are shown. Above the calendar, the day of the week is indicated by the appearance of the proper figure: Monday, Apollo drawn in a chariot by the horses of the sun; Tuesday, Diana drawn by stags; and then Mars, Mercury, Jupiter, Venus, and Saturn in order. Above this is the dial indicating mean solar time. On each side sits an angel. One strikes the first stroke of the quarters on a little bell with a scepter, while the other turns over a sand-glass filled with red sand every hour. Above this a planetarium shows all the motions of the planets. Above this the moon phases are again indicated on a much larger scale. Still higher are figures indicating the four ages and death. The infant strikes the first quarter with a rattle, a young man in the costume of a hunter strikes the half with an arrow, a man dressed as a warrior strikes the three quarters with his sword, and an old man strikes the four quarters with his crutch, whereupon death strikes the hour with a bone. In the gallery above this Christ is seated upon a throne. At noon the twelve

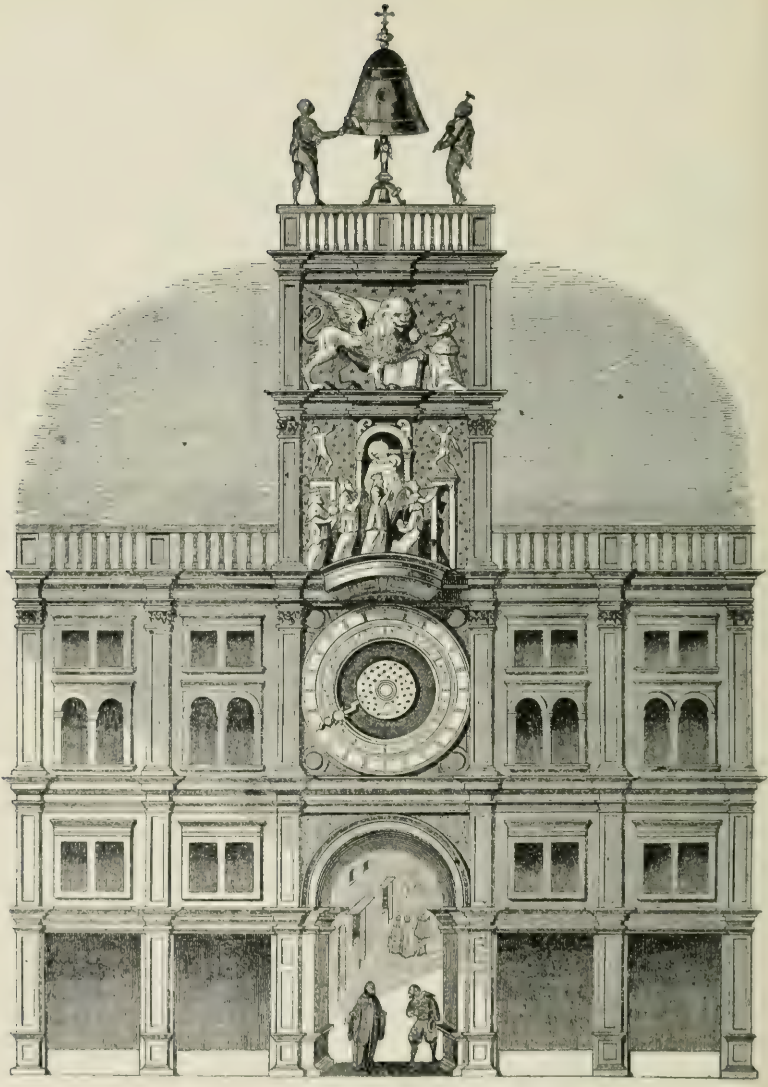


FIG. 321. — THE SECOND VENICE CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

Apostles pass by and bow before Him. At the same time the cock on the top of the left tower crows three times.

The Venice Clock

The fame of the clock located on the clock tower in the Square of St. Mark's at Venice has also spread far and wide. Here, too, there have been three distinct clocks. The first clock was completed by Giovanni P. Rainaldi, of Reggio, and his son Carlo in 1495. Of its construction practically nothing is known.

The second clock was finished shortly after 1600. Fig. 321, which illustrates this clock, is from an old cut in Dubois' excellent *Histoire de l'Horlogerie*. The dial indicates the time, and shows the signs of the Zodiac and the motions of the sun and moon. In the gallery above, the three Magi led by an angel pass by and bow before the Virgin. At the top two bronze giants, Moors, or Men of Ind as they are variously called, strike the hours on the bell with their huge hammers. Evelyn, in his Memoirs, under date 1645, states that he went

"thro' an arch into the famous Piazza of St. Marc. Over this porch stands that admirable clock, celebrated next to that of Strasbourg for its many movements; amongst which, about 12 and 6, which are their hours of Ave Maria when all the towne are on their knees, come forth the three Kings led by a starr, and passing by ye image of Christ in his Mother's armes do their reverence, and enter into ye clock by another doore. At the top of this turret another automaton strikes ye quarters. An honest merchant told me that one day walking in the Piazza, he saw the fellow who kept the clock struck with this hammer so forceably, as he was stooping his head neere the bell to mend something amisse at the instant of striking, that being stunn'd he reel'd over the battlements and broke his neck."

This clock was repaired several times and finally renovated in 1859. Fig. 322 is from a modern photograph. The outside appearance has been but little changed. The time is now shown by "jumping figures" on the two doors on each

side of the figure of the Virgin. These figures change every five minutes. An enlarged view of the central part of the clock is shown in Fig. 323.

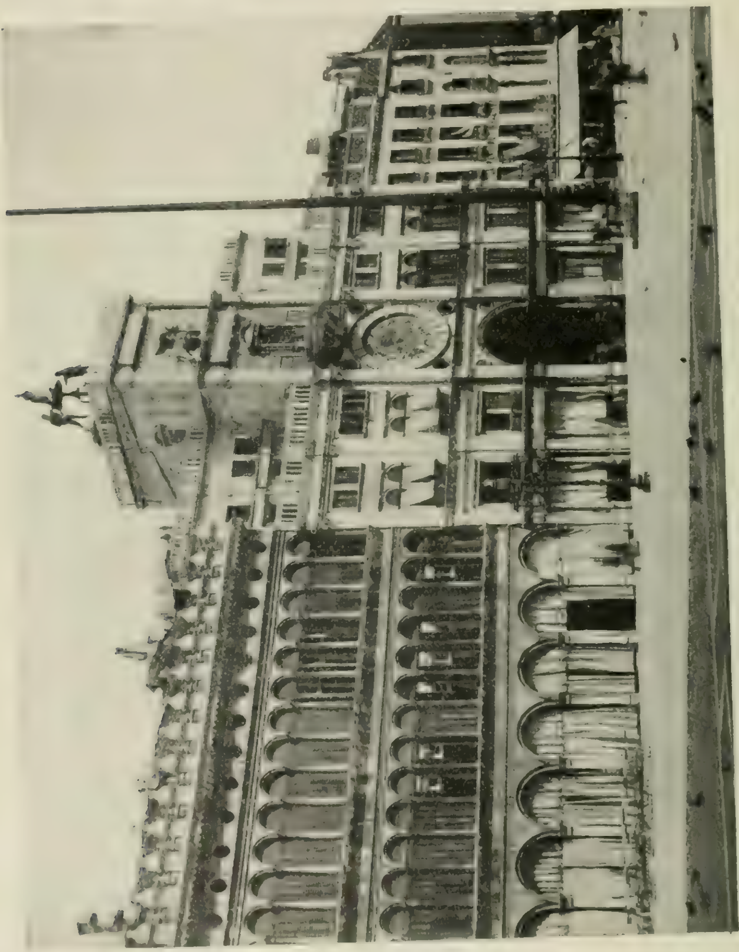


FIG. 322. — THE CLOCK IN ST. MARK'S SQUARE AT VENICE.

Smaller intricate clocks. — It is intended to include under this head those intricate and elaborate clocks which are sometimes copies on a small scale of the cathedral clocks and were often made for exhibition purposes.

One which is often mentioned is Habrecht's clock. It is modeled after the astronomical clock in the cathedral at Strasbourg. This clock was constructed in 1589 by the same Isaac Habrecht, who made the mechanism for the

FIG. 323.—THE CENTRAL PART OF THE CLOCK.

second clock in the cathedral at Strasbourg. It is said that Pope Sixtus V was so pleased with the Strasbourg clock that he ordered Habrecht to make a small one like it. This he did and the clock which he made remained at the Vatican for two hundred years. It next appeared in Holland as the property of William I, King of the Netherlands, who

authorized Odevaere to investigate everything concerning it and to give a description of it, which he did in writing. The clock was exhibited in England in 1850 and then passed into the possession of Mr. Octavius Morgan, who bequeathed it to the nation. It is now in the British Museum in London and is running. It is pictured in Fig. 324. It is about four feet high and the case is of gilt copper with well-engraved figures. The clock has been repaired and changed several times. It now has a pendulum, although originally it was balance controlled. There are three dials and four balconies with moving figures. The lower dial shows the fixed and movable feasts and the motions of the heavenly bodies. The second dial indicates the minutes and the upper one the hours. On the lowest balcony the day of the week is indicated by the appearance of the appropriate deity, on the next balcony there is a procession of angels around the Virgin, on the next the quarters are struck by figures representing the four stages of social life, while on

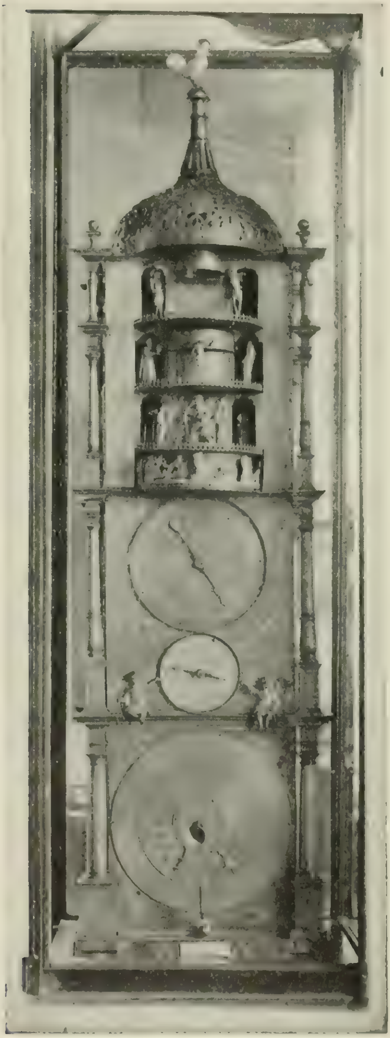


FIG. 324. — THE HABRECHT CLOCK.
(The British Museum, London.)

the upper balcony the hour is struck by a figure of Death. The whole is surmounted by a cock which flaps its wings and crows. It will be seen that this clock is very similar to the big cathedral clock at Strasbourg. In fact it has been said that it shows everything that it did and more besides.

Another clock often mentioned is one which was constructed by Henry Bridges, probably shortly after seventeen hundred. There is an excellent cut of it in existence and this is perhaps the reason why it is so often illustrated and described. This cut is reproduced in Fig. 325. The clock was about 10 feet high and 6 feet broad at the base and in the form of a Roman temple. At the top were three scenes which changed alternately. Below it were the dials which indicated the time, the date, the day of the week, the time of sunrise and sunset, the phases of the moon, the signs of the zodiac, and the like. Below these dials was a representation of a landscape and the sea. On the former vehicles, persons, and animals were seen in motion, and on the latter ships were sailing. Below this another scene represented a carpenter's yard with men at work. There was also an organ which played. This clock was publicly exhibited in 1741 and again in 1770. It was then the property of Edward Davis. But little is known about Henry Bridges except that he was an architect and lived at Waltham Abbey.

Other clocks which are often mentioned are Lovelace's Exeter clock, Fine's clock, and Green's Lichfield clock. Jacob Lovelace of Exeter spent thirty-four years in the construction of his clock and died in abject poverty. This clock was exhibited in 1821 and also at the International exhibition in 1851. It is now in the Liverpool Museum. The Fine clock was commenced in 1553 and finished in 1560 by Oronce Fine, mathematician to Francis I of France. It is 6 feet high and in the form of a pentagonal tower. It is now in the library of St. Geneviève at Paris.

If all literature were searched, descriptions of or references to quite a few of these elaborate clocks would be found.

Many of them have passed out of existence and the rest have usually found their way into museums or private collections.

FIG. 325.—THE BRIDGES CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

Similar clocks have also been constructed in America. The New International Encyclopaedia mentions six of them. The earliest was probably the one made by David Ritten-

house of Philadelphia in 1767. This clock had six dials and showed many astronomical events. Three other cities of Pennsylvania have produced citizens who have added to their fame by making remarkable clocks. These are Donaldson, Hazleton, and Wilkes-Barre. A clock was also constructed by a citizen of Columbus, Ohio, which was 18 feet wide and 11 feet high and had miniature figures which performed various movements. The most famous of these clocks made in America is probably the one which was made by Felix Meyer in 1880 and placed on exhibition in New York. It was 18 feet high, 8 feet wide, and 5 feet deep and had ten years of labor expended on it. It indicated the time at various places, the date, the day of the week, and the motions of the heavenly bodies. Its maker evidently had the Strasbourg cathedral clock in mind, for the first quarter was struck by an infant, the half by a youth, the three quarters by an old man, and the hour by death. As the clock strikes, a figure of Washington rises and extends its right hand, presenting the Declaration of Independence. A door is opened by a servant and all the presidents as far as and including Hayes advance across the platform, salute Washington, and retire.

It is difficult to draw a sharp line of demarcation between the elaborate and intricate clocks such as have been described and elaborate domestic clocks with automatons, meaning by this term clocks, which as far as construction and appearance are concerned, could be appropriately placed in the drawing room of any good-sized house. There are hundreds of these latter clocks. Many of them are in museums, but many are also in private possession. They are, of course, always the work of an individual and are never made in large numbers by any factory. Almost none of them have been constructed during late years.

Modern tower clocks. — In the chapter on "The History, Construction, and Care of Tower Clocks," five modern tower clocks were described more or less at length. These were the Westminster clock on the Houses of Parliament in London; the clock on the tower of the Royal Liverpool Society's

building in Liverpool; the clock on the Metropolitan Life Building in New York City; the clock in the tower of St. Paul's Chapel in New York City; the Colgate & Company clock on their factory in Jersey City. Each one of the clocks is far famed and as a group they are perhaps the five best known modern tower clocks.

There are, of course, thousands and thousands of modern tower clocks and on account of their public location each one is known to a larger or smaller circle of acquaintances. In fact, each reader of this book will immediately think of the best known tower clock in his city or village and wonder why it does not possess more extended fame. Two other clocks in this country which are widely known are the City Hall clock in Philadelphia and the clock on the Union Depot and Ferryhouse in San Francisco. The Philadelphia clock was designed by Warren S. Johnson and completed in 1899. The clockwork is in the main part of the building and is connected with the dial mechanism by means of compressed air. The dials are 25 feet in diameter and 362 feet above the pavement. The total height of the tower is $547\frac{1}{2}$ feet. The San Francisco clock has a Denison gravity escapement, a two-seconds pendulum, and is driven by a weight of 2000 pounds. It is directly connected to the four dials which are 23 feet, 2 inches in diameter. These are the largest dials in America operated directly by a tower clock.

Precision clocks. — There is probably no precision clock whose fame has reached more than a few hundred people at most. In the clock vault in the Naval Observatory at Washington there are three precision clocks which are responsible for the accuracy of the time of the whole country. Hundreds of millions of clocks and watches in daily use throughout the country depend upon them for their time, and yet not one person in a hundred thousand knows that they exist, or who constructed them, or how accurately they keep time.

In the chapter on "Precision clocks — their Construction, Care, and Accuracy," a dozen or more of these clocks were

mentioned. They are probably the best known in the world but even these are but little known.

Domestic clocks. — By this term is meant any clock which, as far as its form, size, and appearance is concerned, could be placed in any room of an ordinary house. Grandfather clocks, nickel alarm clocks, mantel clocks, wall clocks, shelf clocks are all included under this head. The total number in the world must amount to many hundred millions, and yet how few are known individually to even a thousand people.

There are several ways in which a domestic clock may be well known. In the first place it may have belonged to some famous person. George Washington's favorite clock was made by Lépine, a well-known French clockmaker, who was born in 1720 and died in 1805. It is made of brass, covered by a glass case, and wound by a key at the back. It is a typical French mantel clock.

In Fig. 326 is pictured a clock which was given to Anne Boleyn by Henry VIII on her wedding morning in 1532. It is four inches square and ten inches high and made of copper gilt. At the top is a lion holding the arms of England. There is but one hand. On the weights, which are of lead cased in copper gilt, are engraved the initial letters H. A. of Henry and Anne, with a true lovers' knot above and below. At the top of each is "Dieu et mon droit" and at the bottom "the most happye." The clock came eventually into the possession of Horace Walpole and, when his collection was sold, it was purchased in behalf of Queen Victoria for £110 5s. It is now in the corridor of Windsor Castle, supported by a bracket of later date made of carved and gilded wood. The movement has been rebuilt, in fact, practically replaced by a new one. It now has a pendulum instead of the original foliot balance. This clock not only belonged to a famous personage but is also a very early example of a domestic clock.

Another similar domestic clock of early date which was also in the possession of royalty is pictured in Fig. 327. It is now in the possession of Dr. Cranage at Cambridge,

England. At the top may be seen the Stuart arms. These were used by James I, Charles I, Charles II, and James II, and thus the clock must be older than 1688. The dolphin fret reminds one of the bird cage or lantern clock which was

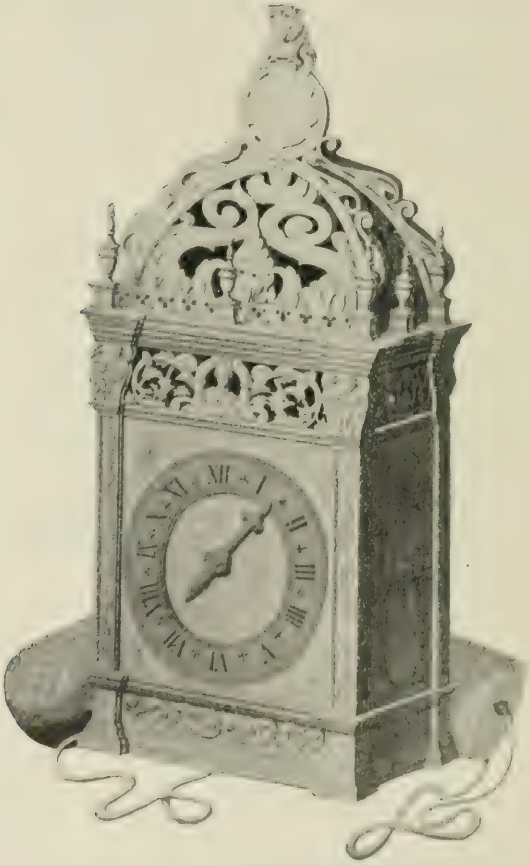


FIG. 326.—THE ANNE BOLEYN CLOCK.
(From DUBOIS, *Histoire de l'Horlogerie.*)

so common in England later. The hood suggests the early Dutch bracket clocks. This clock has but one hand and was originally balance controlled. It probably dates from about the middle of the seventeenth century.

The grandfather clock which was pictured in Fig. 236 on page 350 is also interesting, as it was the first one made

Courtesy Dr. Cranage.

FIG. 327. — A DOMESTIC CLOCK OF EARLY DATE.

by Eli Terry, who did so much to establish clockmaking by factory methods in America.

The two domestic clocks illustrated in Fig. 328 are interesting because they are foreign and look complicated and unusual. They are both in the Egleston collection in

the Metropolitan Museum of Art in New York City. They are nineteenth-century Japanese clocks and have cases of glazed wood. They are balance controlled and have but one hand. Sometimes these clocks have two balances. Then one is in use during the day time and the other during the night, for the Japanese also had the custom of dividing the

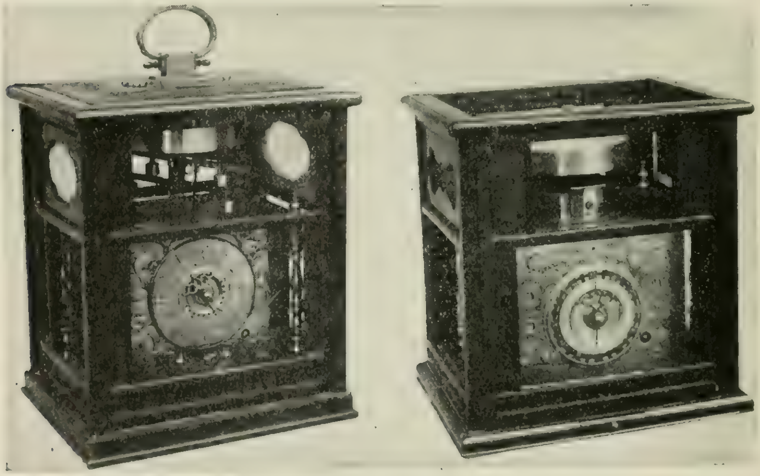


FIG. 328. TWO NINETEENTH CENTURY JAPANESE CLOCKS.
(The Metropolitan Museum of Art.)

day and night into six or twelve equal parts regardless of their length.

Chronometers.—Like precision clocks there is hardly a chronometer that is individually known. A great ocean liner may have navigated the seas in safety for years and carried many thousands of passengers and yet not one of them knew of the chronometers which had made the accurate navigation possible. Probably the best known chronometer is the one constructed by John Harrison which gained for him the £20,000 prize in 1762. This has been described and pictured on page 264. It is now in the Greenwich Observatory.

Watches. — There are several ways in which a watch may become famous. In the first place it may have belonged to a famous historical personage. There are two watches which are both said to have belonged to Oliver Cromwell. The first one is attached to a short fob chain and is now in the British Museum. It was part of the Fellows collection and bequeathed to the Museum by Harriet Fellows, widow of Sir Charles Fellows, of West Cowes, Isle of Wight. It is a small oval watch in a silver case and was made by John Midnall of Fleet Street in 1625. On the silver plate near the end of the fob are the Cromwell crest and the letters O. C. The crest is a demi-lion holding a tilting spear in its paw. John Midnall, the maker of the watch, was warden of the Clockmakers' Company in 1632 and several of his watches are in existence. The other watch is a large oval alarm watch in a fish-skin outer case (see Fig. 329) and has engraved on the inner silver case "Oliver Cromwell" and the date 1638. It was made by Bockel of Amsterdam and was in the Evan Roberts collection. These watches are also both interesting as early examples of pocket watches. They both have but one hand.

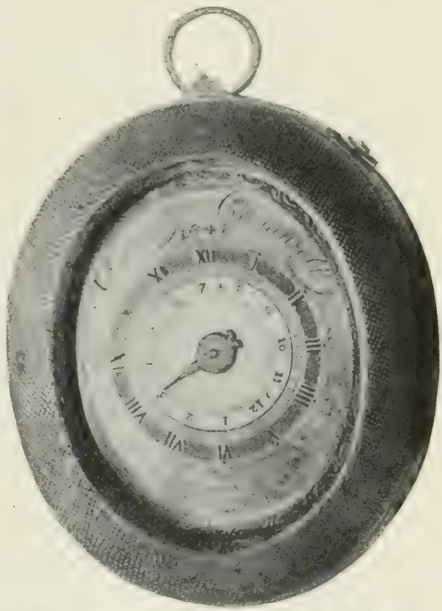


FIG. 329. — OLIVER CROMWELL'S WATCH.

There is also in the British Museum a watch which is said to have been owned by the poet Milton. It was made by David Bouquet, who was a member of the Clock-

makers' Company in 1632 and died in 1665. It is pictured in Fig. 330.

Queen Victoria's favorite watch was an extremely small double-cased watch of gold. It is pendant wound, has a lever escapement, and is numbered 5102. It was made by Bréguet and sold to Queen Victoria on July 17, 1838, for 4250 francs.

FIG. 330. — MILTON'S WATCH.

Another very famous watch is the one shown in Fig. 331. It is famous both because it belonged to a famous person and also because it is such a fine example of a skull watch. It belonged to Mary, Queen of Scots, by whom it was given to Mary Seton, one of her ladies in waiting. From her it descended to Sir George Dick-Lauder, its present owner, who has loaned it to the Royal Scottish Museum at Edinburgh, where it may be seen. It is larger than the usual skull watch and weighs over three quarters of a pound. On the forehead is the figure of death with his scythe, who stands between a palace and a cottage with his toes at the door of each. The inscription runs:

Pallida mors aequo pulsat pede pauperum tabernas regumque turres.
Pale death visits with impartial foot the cottages of the poor and the palaces of kings.

The upper right-hand side shows our First Parents in the Garden of Eden attended by animals with the inscription:

Peccando perditionem miseriam aeternam posteris meruere.
By sin they brought eternal misery and destruction on posterity.

The other side and back, which cannot be seen, portray the crucifixion of the Saviour between two thieves and Time.

The watch is opened by turning it upside down, holding it in the hand, and lifting the lower jaw. What is revealed is shown in Fig. 332. The dial has two hands now but one is evidently a later addition. The excellent engraving shows

FIG. 331. — A SKULL WATCH WHICH BELONGED TO MARY, QUEEN OF SCOTS.

the Holy Family in the stable. In the center of the dial is shown Saturn devouring his children, with the legend:

Sicut meis sic et omnibus idem

It is a striking watch and the movement occupies the position of the brain in the skull. On the plate is engraved "Moyse, Blois" but there is no date. Its probable date is between 1550 and 1600.

A watch may also become famous because it is very

unusual or complicated. A watch may be complicated by having moving figures or by having many attachments. A few of these watches were described in the chapter on "The Attachments to Watches and Complicated Watches."

A watch may be famous on account of its extremely small size. One such has been described on page 431.

FIG. 332.—THE INSIDE OF THE SKULL WATCH.

A watch may also be famous because it was the masterpiece of some famous watchmaker. Bréguet's masterpiece is now the property of Mr. Paul Desoutter. It is $2\frac{5}{8}$ inches in diameter and was ordered in 1783 by an officer in the Marie Antoinette Gardes. It was to contain all complications and improvements then known or possible. It was finally finished in 1802 and cost 30,000 francs. The

parts are of gold instead of brass. The movement is covered back and front with rock crystal, so that it is entirely visible. The dial is also of crystal. It is a minute repeater, has an independent second hand, perpetual calendar, equation of time indicator, and contains a thermometer. It is not wound but winds itself automatically as long as it is worn. This is accomplished by means of a weighted lever, as in a pedometer.

When one considers the total number of timekeepers of all kinds which have become widely known, it is surprising to note how small this number is compared with the number of timekeepers. There are not over a few hundred that are at all generally known, and yet the total number of timekeepers in the world must be well on towards a billion. It is much easier for a person to become famous than a timekeeper!

APPENDIX I

IMPORTANT NAMES AND EVENTS IN THE HISTORY OF TIMEKEEPERS

In this appendix the famous names and the important events in connection with time and timekeepers are arranged in chronological order. It may thus serve in a certain sense as a brief summary of the book. All the material which has been given on previous pages cannot, of course, be repeated. For this reason references have been added so that all the material in connection with any name or event can be readily found.

2000 B.C. or earlier the sun-dial was in use in Babylonia. Pages 31, 35.

About **700** B.C. the first individual sun-dial is mentioned in the eighth verse of the thirty-eighth chapter of Isaiah. Page 35.

About **400** or **500** B.C. the sun-dial was introduced into Greece, perhaps by Berosus. Pages 35, 36.

Berosus; date uncertain; always spoken of as the Chaldean; may have introduced the sun-dial into Greece but more likely invented the hemicyclium form of it. Pages 35, 36.

293 B.C. The first sun-dial in Rome was placed in the temple of Quirinus by Papirius Cursor. Page 37.

200 B.C. The clepsydra was investigated by Ctesibius and perhaps introduced into Greece by him. Page 48.

Ctesibius; date uncertain; son of a barber at Alexandria; preëminent for natural ability and great industry; originated many ingenious devices; said by Vitruvius to have been the first to investigate the methods of making water clocks. Pages 48, 50, 53.

157 B.C. According to Pliny the first water clock was brought to Rome by Scipio Nasica. Page 48.

807 A.D. A very elaborate clepsydra with moving figures was sent to Charlemagne from Bagdad as a present from Haroun-al-Raschid. Page 53.

960–1360 During this period the mechanical clock was invented. Pages 55–73.

Gerbert; a studious Benedictine monk who afterwards became Pope Sylvester II. In **996** he constructed a timekeeper for the Cathedral at Magdeburg and is considered by some as the inventor of the clock. Page 61.

1286 Allowances to the clock-keeper are mentioned in the accounts of St. Paul's, London. Page 62.

1354 The first clock in Strasbourg Cathedral was completed. Pages 72, 498, 513.

1360 or a little later the first unquestioned, mechanical clock of which there is an authentic record was constructed for the Royal Palace of Charles V at Paris by Henry De Vick. Pages 55, 81–85.

Henry De Vick (Wieck or Wyk) constructed the first unquestioned clock; usually spoken of as coming from Würtemberg but perhaps born at Vic near Château-Salins in Lorraine. While working on the clock he was lodged in the tower and paid six "sous parisis" per day. Pages 55, 60, 65, 71, 72, 74, 77, 80–85, 86, 87, 88, 92, 148, 226, 289, 339, 496, 497, 498.

1500 or earlier the small domestic or chamber clock made its appearance. Pages 86, 87.

1500 The mainspring was invented by Peter Henlein of Nürnberg. He is sometimes considered the inventor of the watch, but the early spring-driven timekeepers were probably cylindical boxes (drum shaped) and should be called table clocks or clock-watches. He was, of course, the inventor of the first portable timekeeper. Pages 87, 121, 172, 213, 230.

Peter Henlein or Hele; born about 1480 and died in 1542; a blacksmith by trade; invented the mainspring about 1500 at Nürnberg. Pages 87, 121, 172, 213, 230.

1500 to **1650** The intricate cathedral clock reached the crest of its popularity during this period. Pages 86, 88, 89.

1500 to **1700** The "bird-cage" or "lantern" clock developed and became, particularly in England, the chief domestic clock. Pages 89–94, 148.

About **1510** the stackfreed was first used to equalize the pull of the mainspring. Pages 125, 230.

1525 The fusee was invented by Jacob Zech. Pages 125, 126, 174, 215, 224, 230, 269, 270, 426.

Jacob Zech of Prague; invented the fusee in 1525; died in 1540. Pages 126, 174, 215, 224, 230.

1530 Brass plates for holding the movement began to be used particularly at Nürnberg. Page 153.

1530 Rainer Gemma Frisius mentions the possibility of determining longitude at sea by carrying a timekeeper which would keep the time of some standard meridian. Page 261.

1544 The Paris Guild of Clockmakers was incorporated. Pages 95, 96.

1550 Screws began to be used about this time. Pages 153, 215.

1560 Oval or egg-shaped watches appeared about this time; also many-sided watches. Pages 133–135.

1580 Toy watches in the shape of fruit, flowers, insects, crosses, and the like came into vogue. Pages 135–137.

1587 Watchmaking was introduced as an industry into Geneva, Switzerland, by Charles Cusin, who came as a refugee from Autun in Burgundy. Pages 123, 430.

Bartholomew Newsam; a Yorkshireman who came to London and resided in the Strand near Somerset House; appointed, in 1572, clockmaker to Queen Elizabeth; died in 1593; there are several fine examples of his work. Pages 138–141.

Richard Crayle; one of the petitioners for the incorporation of the Clockmakers' Company; an early maker of repute; died about 1655. Pages 139–141.

David Ramsay; a watchmaker of particular renown; was first master of the Clockmakers' Company; clockmaker to James I; died about 1654. Page 94.

Edward East; watchmaker to Charles I; resided for a time in Fleet St.; there are many examples of his work in existence; one of the ten original assistants of the Clockmakers' Company; warden in 1639, master in 1645 and 1652; died not long after 1693 at a very advanced age. Pages 140, 141, 220, 221.

1600 The spring-driven table clock was at the height of its popularity. Pages 127–133.

1600 The *pocket* watch came into use just a century after the invention of the mainspring and the consequent introduction of portable timekeepers. During this century all watches had been cylindrical boxes, oval, many sided, of "toy" watches. There may have been a very few circular watches. Pages 133–137, 213, 214.

1610 Watch glasses to protect the dial began to be used. Rock crystal may have been used a little earlier. Page 215.

1610 Enamel began to be used in decorating the cases of watches. Page 217.

1631 On August 22 a charter was granted to the Clockmakers' Company of London. Pages 94, 95.

1632 Enamel painting in colors became the leading method of decorating watch cases. Page 217.

1635 Enamel dials were invented by Paul Viet, of Blois, France.

1640 Outer protective cases of horn, shagreen, tortoise-shell, etc., began to be used. A watch then had two, sometimes three, cases. Pages 219–223.

1600–1664 The fusee chain was invented by Gruet, of Geneva, to replace the gut previously used. The date is variously given. Pages 126, 224.

1658 The pendulum was applied to clock mechanism. The honor of its invention is usually given to Christian Huygens, although there are many other claimants, chief among them, Robert Hooke, and Ahasuerus Fromanteel. Pages 142–145.

1658 The balance spring for watches was invented by Robert Hooke. It was a straight spring, however, and did not differ much from the hog's bristle which had been used for some little time to check the movements of the balance wheel. The curved form was invented in 1674 by Abbé de Hautefeuille and Huygens. Pages 224, 233.

1660–1670 The "grandfather" clock came into existence. The first cases were of oak or painted pine. A little later veneering and the use of panels and inlay work was brought about by the desire for ornamentation. Pages 148–154.

1676 The anchor escapement of the recoil type was invented by Robert Hooke. The foliot, verge, and crown wheel were now replaced by the pendulum, anchor escapement, and escape wheel. Pages 77–79, 146, 181–187.

1676 The rack and snail striking mechanism for clocks was invented by Edward Barlow. He also invented the repeating clock. Pages 197, 202, 203, 204, 206, 245, 246, 295, 442.

Edward Barlow (Booth) was born near Warrington in 1639. He took the name, Barlow, from his godfather, Ambrose Barlow. He was very ingenious and devoted much time to timekeepers. In 1676 he invented the rack and snail striking mechanism for clocks. This made possible the repeating clock. He invented the repeating watch in 1686 and applied for a patent, but it was opposed by Daniel Quare whose watch was judged the better. He invented the cylinder escapement which was patented in 1695 in connection with William Houghton and Thomas Tompion. He died in 1719. Pages 197, 206, 245.

Robert Hooke was born at Freshwater, Isle of Wight, July 18, 1635. He entered Christ Church College, Oxford, in 1653. He was a teacher, an inventive genius, and a writer upon most of the scientific questions of his day. He was experimenting with the pendulum at the same time as Huygens and is considered by some the inventor of the pendulum clock. In 1658 he invented the balance spring for watches. It was a straight spring and like the hog's bristle which had been used from about 1600. In 1676 he invented the anchor escapement of the recoil type. He was very versatile and seldom struck to one thing until successful. He died at Gresham College, March 3, 1703. Pages 142, 143, 146, 181, 224, 233, 261.

Christian Huygens was born in Holland, April 14, 1629. His birthplace was probably Zulichem and this is often used for him almost as a second family name. In 1665 he was invited to Paris by Louis XIV to found a Royal Academy of Sciences. He returned to Holland in 1681 and died there in 1695. In 1657 he produced his first pendulum clock and in 1673 his work on the clock was published at Paris. He was not merely a clockmaker but a great scientist, interested particularly in Mathematics and Physics. Pages 142, 143, 145, 146, 174, 188, 189, 224, 233, 261, 273.

Ahasuerus Fromanteel. The Fromanteel (Fromantel, or Fromantil, or Fromenteele) family was of Dutch extraction and lived in England. There were two or perhaps three Ahasuerus Fromanteels who lived within a few years of the same time, and all were clockmakers. One was a personal friend of Huygens and introduced the pendulum into England. Pages 142, 143, 144.

1674 The curved balance spring for watches was introduced by Abbé de Hautefeuille and Huygens. Pages 224, 233.

1675 The Greenwich Observatory was founded. Page 260.

1680–1690 The minute hand was added, perhaps by Quare. Page 146.

1687 The repeating watch was invented by Barlow and Quare. Page 245.

1695 The cylinder escapement was invented by Thomas Tompion. This is not used in pendulum clocks but in watches and balance-controlled clocks. It was patented (No. 344) in the name of Barlow (Booth), Houghton, and Tompion. Pages 107, 181, 225, 235–238, 441.

1700 or a little earlier ormolu and Buhl work came into vogue as the chief way of decorating French clocks. Page 157.

1700 Jewels were first used in watches. The art of piercing jewels was invented by Nicholas Facio (or Facie) who was born in Basle in 1666 and died in Worcester, England, in 1753. Pages 115, 225, 232.

1700–1720 The pedestal clock similar to the grandfather clock developed in France. Pages 159–163.

Daniel Quare was born in 1648. His place of business during most of his life seems to have been at the King's Inn, Exchange Alley. In 1687 he invented along with Barlow the repeating watch. In 1708 he was master of the Clockmakers' Company. He had one son and three daughters and died at Croydon, March 19, 1724. There are quite a number of excellent examples of his workmanship. It is said that he was the first to give watches a serial number. Pages 220, 221, 245.

1710 Lacquer work on the cases of grandfather clocks made its appearance. Page 150.

1714 The "Commissioners for the discovery of longitude at sea" offer a prize of £20,000 for the determination of longitude at sea within certain limits of accuracy. Pages 261, 262.

1715 The anchor escapement of the dead-beat type was invented by George Graham. Pages 146, 147, 185–187.

1720 The cylinder escapement, invented by Tompion in 1695, was improved and put into practically its present form by George Graham. Pages 225, 235–238.

1722 The mercurial pendulum for eliminating the effect of temperature changes was invented by George Graham. Pages 147, 192, 193.


FIG. 333.—THOMAS TOMPION, 1639–1713.

Thomas Tompion (Fig. 333), often called "the father of English watchmaking" was born at Northhill, Bedfordshire, in 1639. When still a young man he was in business as a clockmaker at Water Lane,

Blackfriars. His shop was known by the sign of the Dial and Three Crowns. He was associated as a brother of the Clockmakers' Company in 1671. He became a freeman in 1674, was chosen assistant in 1691, warden in 1700, 01, 02, and master in 1704. He became the leading watchmaker at the court of Charles II. Those who could be compared with him are Quare, Graham, and perhaps Knibb. In 1695 he invented the cylinder escapement for watches. He died in 1713 and is buried in Westminster Abbey. He was unmarried and bequeathed his business to George Graham. Pages 63, 90, 93, 94, 150, 219, 220, 225, 235, 252, 253, 501.

George Graham (Fig. 334) was born at Kirklinton, or Rigg, Cumberland, July 7, 1673. He tramped to London at an early age and in 1688

FIG. 334.—GEORGE GRAHAM, 1673-1751.

commenced his apprenticeship to Henry Aske. He was admitted a freeman of the Clockmakers' Company in 1695 and entered the service of Thomas Tompion at once. Later he married his niece and when Tompion died in 1713 he inherited his business. In 1715 he invented the anchor escapement of the dead-beat form. In 1720 he improved the cylinder escapement which had been patented by Barlow, Houghton, and Tompion in 1695. In 1721 he invented the mercury pendulum.

He was warden of the Clockmakers' Company in 1719, 1720 and 1721, and master in 1722. He died in 1751. Tompion's grave in Westminster Abbey was opened to receive the body of Graham. The inscription on the stone which marks the spot is as follows:

"Here lies the Body of Mr. Tho Tompion who departed This Life the 20th of November 1713 in the 75th Year of his Age. Also the body of George Graham of London Watchmaker and F. R. S. Whose curious inventions Do Honour to ye British Genius Whose Accurate Performances Are ye Standard of Mechanical Skill. He died ye XVI of November MDCCLI. In the LXXVIII year of his Age."

The London Daily Advertiser for Nov. 18, 1751, contains this notice:

"Saturday evening, died suddenly, at his house in Fleet Street, Mr. George Graham, not less known in the learned world, than in the branch of Business to which for many Years he had so successfully applied himself, as by his uncommon Ingenuity to have acquired the Reputation of being the best Watchmaker in Europe. He was many Years Fellow and one of the Council of the Royal Society. His Apparatus, made for measuring a Degree of the Meridian in the Polar Circle, is greatly esteemed among the Literati, as are also his many curious Instruments for Astronomical Observations. He lived beloved and died universally lamented." Pages 146, 147, 155, 156, 185, 192, 225, 235, 262, 266, 335–341.

1724 The duplex escapement was invented by Jean Baptiste Dutertre. It was improved in 1759 by Pierre LeRoy. Pages 225, 235.

1726 The gridiron form of compensating pendulum was invented by John Harrison. Pages 147, 193, 262.

About this time maintaining power was introduced by John Harrison. Pages 174, 175, 231.

FIG. 335.—A WATCH WITH PINCHBECK OUTER CASE.
(The Metropolitan Museum of Art.)

Christopher Pinchbeck was born in 1670. In London he was in business first at Clerkenwell and then in Fleet Street. He was famous chiefly as the maker of astronomico-musical clocks and the inventor (1721) of an alloy which resembled gold. It consisted of about three parts of zinc and four of copper and was called pinchbeck. He died Nov. 18, 1732. In Fig. 335 is illustrated a watch by William Webster with a pinchbeck outer case. It is in the Metropolitan Museum of Art

in New York City. The watch is signed on the movement: William Webster Exchange Alley" and is numbered 11064. Webster died in 1735.

John E. Ellicott was born in 1706 and was in business in Sweeting's Alley in 1728. In 1753 he invented a form of compensation pendulum in which the pendulum bob rested on two levers and was moved up or down with temperature changes. The device was never widely used. He was clockmaker to George III. He died suddenly in 1772. In Fig. 336 is illustrated a grandfather clock by Ellicott with this peculiar pendulum device. The clock is in Harvard College Observatory at Cambridge, Mass.

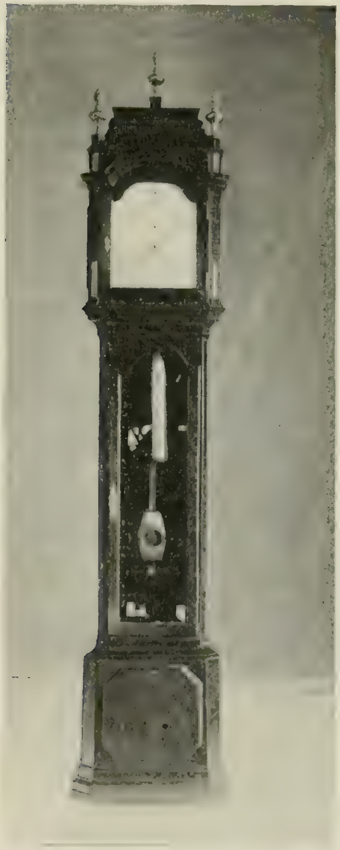


FIG. 336. — A CLOCK, BY ELLICOTT.
(Courtesy, Harvard College Observatory.)

1730 The first cuckoo clock was constructed by Anton Ketterer of Schönwald in the Black Forest. Page 170.

1735 Harrison made his first chronometer. Page 262.

1750 The cases of grandfather clocks began to be made of mahogany. Page 150.

1750 The detached lever escapement was invented by Thomas Mudge. Pages 225, 235.

1753 The pin wheel escapement was invented by Lepaute. It has now fallen out of use. Page 187.

1761 Harrison took the £20,000 prize with his fourth chronometer which kept time at sea within the required limits. Pages 263, 264.

1761 Berthoud completed his first chronometer. Page 266.

John Harrison; born 1693, died 1776; one of the great figures in the history of horology. For biography and portrait see pages 262–265. Pages 147, 175, 193, 227, 231, 233, 262–265, 280, 532.

1765 Pierre LeRoy invented, in principle at least, the detent escapement used in chronometers. Pages 235, 265.

Pierre LeRoy, the eldest son and successor of Julien LeRoy, was born in 1717. He improved the duplex escapement for watches in 1759. He invented, in principle at least, the detent escapement for chronometers

about 1765. Considered by some the greatest of French horologists. He died in 1785. Pages 225, 233, 235, 265, 266, 267, 270.

Ferdinand Berthoud was born in Plancemont (Fig. 337) March 19, 1727. In 1745 he visited Paris and settled there. He improved LeRoy's detent escapement and wrote many works on horological subjects. He was a man of real talent and great energy. He died at Groslay, June 20, 1807. Pages 265, 266, 267, 270.

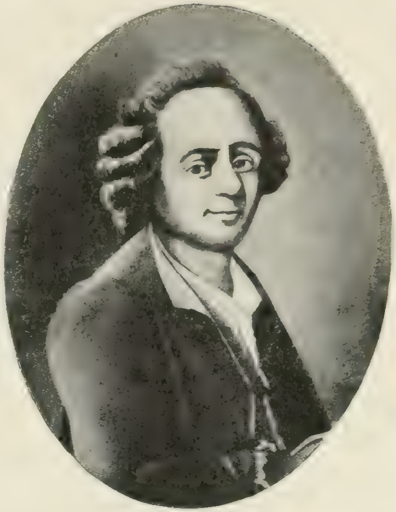


FIG. 337. — FERDINAND BERTHOUD, 1727–1807.

Thomas Mudge was born at Exeter in 1717. He was apprenticed in 1729 to Graham and, on his death, succeeded to the business. In 1765 he invented the detached lever escapement for watches. His first chronometer was sent to the Greenwich Observatory in 1774. He received, all told, £3000 from the Board of Longitude for his inventions in connection with chronometers. He died Nov. 14, 1794. Pages 221, 222, 225, 235, 265–267.

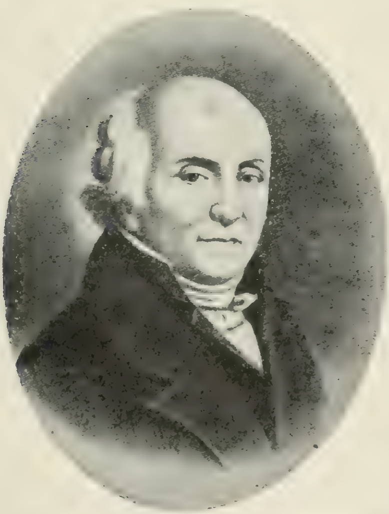


FIG. 338. — ABRAHAM LOUIS BREGUET 1747–1823.

Abraham Louis Bréguet was born in Neuchâtel (Fig. 338), Switzerland, Jan. 10, 1747. He came early to Paris and there achieved a great success. He was a man of high attainments, great inventive genius, and remarkable ingenuity. He published nothing, so that he must be judged by the timekeepers which have come down to us and by his inventions. He invented the "tourbillon" or revolving carriage in which the escapement was placed to avoid position errors. He invented the "parachute" or yielding bearing surfaces for the balance staff pivots. He also invented the Bréguet or overcoil hairspring. He was easily the

leading horologist of his times and died in Paris, Sept. 17, 1823. Pages 109, 117, 233, 239, 265, 266, 328, 534, 536.

1770 Engine turning as a method of decorating watch cases came into use; invented by Francis Guerint. Page 223.

1775 John Arnold invented the cylindrical balance spring for chronometers. Pages 265, 267.

1776 Lépine introduced very thin watches.

1780 Earnshaw put the chronometer into its present form. Page 268.

John Arnold; born 1736, died 1799. See pages 265, 267 for his biography. Pages 233, 235, 265, 267, 268, 270, 427.

Thomas Earnshaw; born 1749, died 1829. See pages 265, 268 for his biography. Pages 235, 265, 268, 269, 270, 428.

1780 The second hand was now usually added. Page 225.

1790–1820 Musical watches and those with moving figures appeared. Pages 253–255.

1800 Watch cases were now often decorated with pearls.

Jean Antoine Lépine was born in Challex (or Gex), France, Nov. 18, 1720. When twenty-four he went to Paris and eventually became watchmaker to Louis XV. He invented the going barrel and was the first to make very thin movements. He became blind and died May 31, 1814. Page 529.

Jacques Frédéric Houriet was born in Chaux d'Abel in 1743 and died in 1830. He was brother-in-law of Urban Jürgensen, lived in Le Locle, Switzerland, and was the founder of chronometer making in Le Locle.

1800 Eli Terry was using power-driven tools for making clocks. His shop in Plymouth may be considered the first clock factory in America. Page 350.

1802 The banjo clock was patented by Simon Willard. Page 374.

1807 The firm of Terry, Thomas, and Hoadley was formed to manufacture clocks at Greystone, Conn. Page 351.

1814 Terry patented his shelf clock which he called his "Perfected wood clock." Page 352.

Eli Terry; born in South Windsor, Conn., April 13, 1772; died Feb. 24, 1852; the father of clockmaking by factory methods in America. For biography and portrait see pages 348–356. Pages 348–364, 372, 382.

Seth Thomas; born in Wolcott, Conn., Aug. 19, 1785; died Jan. 29, 1859; associated with Terry and Hoadley in the first clock firm in 1807; founder of the Seth Thomas Clock Co. For biography and portrait see pages 356, 357. Pages 350, 351, 353–364, 372.

Thomas Reid; a famous Edinburgh clockmaker; born 1746; apprenticed to Jas. Cowan who had studied in London and in Paris under Julien LeRoy; he succeeded him in 1781; in partnership with William Auld from 1806 to 1823; died 1831 (sometimes stated, born 1750; died 1834); author of *A Treatise on Clock and Watchmaking* which was standard for many years.

Urban Jürgensen; born at Copenhagen, Aug. 5, 1776; an eminent Danish horologist and chronometer maker; studied in Neuchâtel, Geneva, Paris, and London; in Paris he was associated with Bréguet and Ferdinand Berthoud; author of *The Higher Horological Art* and *Principes de la Mesure du Temps;* died May 14, 1830; his son, Jules Frederick, was born in Le Locle, Switzerland, in 1808 during a brief sojourn of his parents there; he founded a firm there in 1835 which has continued to the present time and makes the well-known Jürgensen watches. Pages 431, 433, 434.

Antide Janvier; born at Saint Claude in the Jura in 1751; settled in Besançon; a fine mathematician and horological expert; published in 1811, *Essai sur les Horloges;* died Sept. 23, 1835.

Edward John Dent; born 1790; died 1853; his stepson Frederick (Rippon) Dent completed the Westminster clock in 1854. For biography see page 427. Pages 281, 306, 308, 339, 427.

Benjamin Lewis Vulliamy; son of Benjamin, son of Justin, belonged to a noted family of clockmakers of Swiss origin; born in 1870; was clockmaker to Queen Victoria; master of the Clockmakers' Company five terms between 1821 and 1848; Windsor Castle contains many fine examples of his work; it was intended by the architect that he should make the Westminster clock, but the plans of Dent were considered better. He died in January, 1854. Page 306, 501.

1825 The so-called "Bronze Looking-Glass" shelf clock was invented by Chauncey Jerome. Page 359.

1837 The one day brass shelf clock was invented by Chauncey Jerome. Pages 361, 362.

1842 The first consignment of brass shelf clocks was sent to England. Pages 362, 363.

Chauncey Jerome; born in Canaan, Litchfield Co., Conn., June 10, 1793; the inventor of the Bronze Looking-Glass shelf clock and the one day shelf clock with brass movement. For biography and portrait see pages 358–364. Pages 352–365, 367, 368, 371, 382, 457.

Hiram Camp; son of Samuel Camp, Jr., and Jeanette Jerome, sister of Chauncey Jerome; born in Plymouth, Conn., April 9, 1811; left home at eighteen and went to Bristol to work at clock manufacturing with his uncle. In 1845 he removed to New Haven and was president of the New Haven Clock Co. for about forty years; died July 8, 1893. Page 364.

Joseph Thaddeus Winnerl; born in Mureg, Styria, Jan. 25, 1799; settled in Paris in 1829; celebrated as a maker of chronometers and precision clocks; maker of the chief clock of the Paris Observatory; died in 1886. Pages 333, 437.

Adolf Ferdinand Lange; born in Dresden, Germany, in 1815; established a school for watchmakers in Glashütte in 1845; died Dec. 5, 1875. Pages 282, 437.

Claudius Saunier (Fig. 339); born at Macon, France, in 1816; worked for Patek, Philippe & Cie, at Geneva; author of the very large and valuable work *Traité d'Horlogerie Moderne*, 1870, which has been translated into English and other languages; never financially successful and died poor in 1896. Pages 209, 211, 212, 246.

FIG. 339. — CLAUDIUS SAUNIER, 1816–1896.

Edmund Beckett Denison; born in 1816; elected president of the British Horological Institute in 1868; succeeded his father as a baronet, taking the title of Sir Edmund Beckett in 1874; called to the House of Lords under the title of Baron Grimthorpe in 1886; designed the Westminster Clock; author of *Clocks and Watches and Bells* which has a very large sale; died in 1905. For biography see page 306. Pages 181, 290, 300, 306, 308, 335, 341, 441.

Victor Kullberg; born at Wisby, on the Island of Gothland, Sweden, in 1824; came to London in 1851; a brilliant horologist and successful chronometer maker; founder of the present day firm of V. Kullberg, 105 Liverpool Road, London, N.; died July 7, 1890. Page 281, 426, 427.

Moritz Grossmann; born in Saxony in 1826; settled in Glashütte in 1854; successful manufacturer of timekeepers and author of several articles and books on horological subjects; died Jan. 23, 1885.

1850 The model of the first watch to be made by factory methods by Dennison and Howard was completed. Page 396.

1853 The first factory-made watch was put on the market. Page 396.

1854 The watch factory was moved from Roxbury to Waltham. Pages 396, 397.

1857 The company was obliged to make an assignment. Page 397.

1865 The Elgin Watch Factory was established. Page 402.

Aaron L. Dennison; born March 6, 1812 in Freeport, Me.; died in Birmingham, England, Jan. 9, 1895; associated with Edward Howard in the first watch factory in America. For biography and portrait see pages 392–398.

Edward Howard; born Oct. 6, 1813, in Hingham, Mass., died in 1904; associated with Aaron L. Dennison in founding the first watch factory in America. For biography and portrait see pages 392–398.

1872 Watch testing began at Geneva. It commenced at Neuchâtel in 1876, at Kew in 1884, and at Besançon in 1885. Pages 481–494.

1921 The Horological Institute of America was organized. The first conference was called by the National Research Council for May 19 and 20, 1921. At a later conference, Oct. 20 and 21, 1921, the Horological Institute of America was organized. Its purpose is to coöperate with individuals and with other organizations, in a sincere endeavor to advance the interests of horological science and practice. At present it is engaged in the very practical matters of standardizing the curricula of horological schools and of the certification of watchmakers.

APPENDIX II

TECHNICAL TERMS IN CONNECTION WITH CLOCKS AND WATCHES

The following pages contain a short glossary of many of the more important technical terms used in connection with clocks and watches. No attempt has been made to make the list complete [1] although all of the more usual and important terms are probably included. The French and German equivalents[2] have also been added. Each term is followed by a short definition and a reference to the page or pages where the subject is fully treated.

Addendum, Arrondi, die Wälzungshöhe.

That portion of the tooth of a wheel or pinion which extends beyond the pitch circle. Pages 178–180.

Adjusting for temperature, Réglage aux températures, die Temperaturkompensationsberichtigung.

Arranging the screws on the compensation balance so that the time of swing will be as nearly as possible the same for a considerable range of temperature. Pages 117, 118.

Adjusting for position.

Manipulating the balance and balance spring so that the watch does not change its rate in different positions. Pages 118, 119.

Adjusting for isochronism.

Manipulating the balance spring so that the watch does not change its rate when the balance swings through a long arc or a short one. Pages 116, 117.

Alarm, Réveille-matin, der Wecker.

The mechanism attached to a timekeeper whereby at any set time a hammer strikes rapidly on a bell for several seconds. Pages 204, 206, 243, 244.

[1] The two most excellent books: Abbott, *American Watchmaker and Jeweler*, and Britten, *Watch and Clockmakers' Handbook*, contain much longer lists. In fact these books are really treatises on clock and watch making and repairing, and both are arranged in the form of an encyclopædia.

[2] A very much longer list of French and German equivalents can be found in the following books: Britten, *Watch and Clockmakers' Handbook;* Grossman, *Horological Pocket Dictionary, English-German-French* (Bautzen, 1891); *Vocabulaire de poche pour l'horloger, français-allemand-anglais* (Bautzen, 1891); *Taschen-Wörterbuch für Uhrmacher, deutsch-englisch-französisch* (Bautzen, 1903). (There are three separate volumes); Heaton, Edward, *Terminologie horlogère française et anglaise*, 3 + 75 pp., Bienne, 1918; Wershoven, *Technical vocabulary, English and German, Vocabulaire technique, français-allemand* (Leipzig, 1885); E. Bassermann-Jordan, *Uhrn.* (This contains a very short "*deutsch-english-französisches, Wörterverzeichnis.*")

Alloy, Alliage.
A mixture of two or more metals. Pages 193, 275.

Anchor escapement, Echappement à ancre, die Ankerhemmung mit Rückfall or *der rückfallende Hackengang.*
The escapement used in most domestic clocks. Pages 77–79, 146, 181–187, 341.

Arbor, Arbre, die Welle.
The axle on which a wheel turns. Pages 76, 106, 107, 178, 231, 232, 269.

Auxiliary compensation, Compensation auxiliaire, die Hilfscompensation.
A device added to a compensation balance to allow still more closely for temperature changes. Pages 274, 275, 283.

Balance, Balancier, die Unruhe.
The vibrating wheel in a watch or chronometer which regulates the motion of the train. Pages 108–113, 232, 233, 270–272.

Balance spring, Ressort spiral, die Spiralfeder, or *Spirale.*
Often called the hairspring. A long, fine, spiral spring which determines the time of swing of the balance. One end is fastened to a collet which is attached to the balance staff and the other to a stud which is attached to the watch plate. Pages 108–113, 224, 225, 233, 234, 270, 271.

Balance staff, Axe de balancier, die Unruhwelle.
The axis or arbor which carries the balance wheel. Pages 108–113, 411–413, 468.

Banking pins, Goupilles de renversement, die Prellstifte.
In general pins which circumscribe or limit the motion of a moving part. In particular the two pins which limit the motion of the lever in a lever escapement in a watch. Page 109.

Bar movement, Mouvement à ponts, das Klobenwerk.
Often called a bridge-model movement. One plate is omitted and its place is taken by a number of bars extending over the movement and carrying the upper pivots. Page 101.

Barrel, Barillet, das Federhaus.
A cylindrical box which contains the mainspring. Pages 103–105, 229, 269.

Bezel, Lunette, der Glasreif.
The grooved metal ring of a watch or clock which holds the crystal or glass. Page 215.

Bob, Lentille, Pendellinse.
The mass of metal (usually lens shaped) at the bottom of a pendulum. Pages 188, 190–194, 441.

Bréguet spring, spiral Bréguet, die Bréguet Spiralfeder.
A balance spring the outer coil of which has been raised above the others and carried towards the center. Named after the inventor. Pages 109, 117, 233, 266.

Brocot suspension, Suspension Brocot, Brocot's Pendelaufhängung.
The method of suspending a pendulum so that it can be raised or lowered by means of a key from the front of the dial.

Cam, Doigt de levée, die Hebescheibe.
A piece of metal of irregular contour which turns about a center and thus imparts variable motion to any lever or piece pressing against it. Pages 212, 247, 326.

Canon pinion, Chaussée or *minuterie à canon, das Viertelrohr.*
The pinion to which the minute hand is attached. It is hollow and fits on the center arbor. Pages 113, 114, 196.

Castle ratchet.
The wheel in a stop watch which has a toothed edge and also upright teeth and which, by turning, causes the various motions in order. Pages 247, 249.

Center-seconds hand, Seconde au centre, Sekunde aus der Mitte.
A long second hand moving from the center of the dial and not from a separate center over a different part of the dial as is usually the case. Page 247.

Chime barrel, Rouleau de carillon, die Stiftenswalze.
A cylinder with projections on its surface which, as it turns, raises the various hammers in order. Pages 204, 295.

Chronometer, Chronomètre, das Chronometer.
An accurate portable timekeeper of special design. Pages 260–288.

Chronometer escapement, Echappement à détente, die Chronometerhemmung.
A special escapement, often called a detent escapement, always used in chronometers. Pages 107, 181, 235, 265, 270–272.

Clepsydra, Clepsydre, die Wasseruhr.
A water clock. Pages 48–53, 57.

Click, Cliquet, Sperrkegel.
A pawl or dog which falls into a ratchet wheel and prevents it from turning backwards. Pages 75, 83, 104, 105, 229.

Club tooth, Dent à talon, der Kolbenzahn.
A specially shaped tooth used in escape wheels which has part of the impulse angle on the tooth. Page 108.

Collet, Collet, der Putzen.
In general a collar or band of metal, in particular the hub on the balance staff to which one end of the balance spring is attached. Pages 109, 117, 119.

Compensation balance, Balancier compensé, die Kompensationsunruhe.
A balance constructed of two metals so as to counteract temperature changes. Pages 108–113, 117, 118, 232, 233, 270–272.

Compensation pendulum, Pendule compensé, das Kompensationspendel.
A pendulum in which the effect of temperature changes has been counteracted. Pages 190–194, 262.

Crown wheel, Roue de champ, das Kronrad.
A contrate wheel whose teeth are set at right angles to its plane. Pages 60, 83–85, 88, 92, 123, 145, 163.

Crutch, Fourchette de pendule, die Pendelgabel.
The wire which connects the anchor to the pendulum rod. Pages 79, 187, 202, 355, 443.

Curb pins, Goupilles de raquette, die Rückerstifte.
The two small pins which embrace the balance spring and by being moved make a watch go faster or slower. Pages 112, 233.

Cylinder escapement, Echappement à cylindre, die Zylinderhemmung.
A particular kind of escapement in which the balance is attached to a cylinder. The teeth of the escape wheel are of special form and act on this cylinder. Pages 107, 181, 225, 235–238.

Damaskeening.
Decorating a metal surface with rings and bars as in the case of the plates of a watch. This should perhaps be called snailing instead. Page 101.

Dead-beat escapement, Echappement à repos, die ruhende Hemmung.
An escapement in which the escape wheel does not recoil but remains at rest except during actual impulsion. Pages 146, 147, 185–187, 290, 296, 335, 341.

Detached escapement, Echappement libre, die freie Hemmung.
An escapement in which the balance or pendulum is connected with the time train only during a small part of its swing. Pages 107–113, 181, 225, 234, 235, 238, 275.

Detent escapement, Echappement à détente.
Another name for the chronometer escapement.

Dial, Cadran, das Zifferblatt.
The face of a watch or clock upon which the numerals are placed to indicate the time. Pages 59, 195, 196, 239, 272, 294.

Dog screws, Vis clef, die Schlüsselschraube.
Screws with half heads for holding the movement of a watch in its case. Page 469.

Double sunk dial, Cadran à centre rapporté, Eingesetztes Stunden und Sekundenblatt.
A dial having recesses for the hour and second hands. Page 415.

Duplex escapement, Echappement duplex, die Duplexhemmung.
An escapement in which the escape wheel has two sets of teeth. Pages 107, 181, 225, 237, 238, 407.

End stone, pierre de contre pivot, der Deckstein.
A small disc of jewel upon which a watch pivot rests. Often called a cap jewel. To be found only in the escapement and no watch has more than six. Pages 114–116, 471.

Engine turning, Guillochis, das Guilloche.
The decoration of a watch case by means of circular wavy curves. Pages 223, 418, 419.

Escapement, Echappement, die Hemmung.
That part of the movement of a clock or watch which controls the rate of running. Pages 77, 107.

Escape wheel, Roue d'échappement, das Gangrad.
The wheel of the escapement which is allowed to go forward one tooth at a time. Pages 108, 109, 181–187, 270–272.

Fan-fly, Volant, der Windfang.
A fan with two blades used in clocks to keep the interval between the strokes of the hammer uniform. Pages 57, 58, 198, 295, 297, 301.

Full plate, deux Platines, das Vollplatinenwerk.
A watch movement with two complete plates. Pages 99–101.

Fusee, Fusée, die Schnecke.
A cone-shaped, grooved pulley to equalize the pull of the main-spring. Pages 125, 126, 174, 215, 224, 230, 269, 270, 426, 441.

Gimbals, Suspension de chronomètre, die Universalaufhängung.
A contrivance for holding a ship's chronometer so that it will always be level and not affected by the ship's motion. Pages 265, 273, 274, 278, 280.

Gold Spring, Ressort d'or, die Goldfeder.
A very thin spring made of gold and part of the detent escapement of a chronometer. Pages 271, 272.

Gravity escapement, Echappement à gravité, die Schwerkrafthemmung.
An escapement used especially in turret clocks where the impulse is given to the pendulum by means of the weight of a lever which has been raised by the train. Pages 290, 292–294, 302, 308, 335, 341.

Hairspring (see *balance spring*).

Hands, Aiguilles, die Zeiger.
The revolving pointers which indicate the time. Pages 79, 113, 294, 295.

Isochronism, Isochronisme.
Requiring the same interval of time for a swing. Pages 116, 117, 189, 190, 462–464, 468.

Jewel, Pierre.
A precious stone which is pierced to receive the pivot. Pages 114–116, 225, 230, 232, 469, 471.

Lantern pinion, Pignon à lanterne, das Hohltrieb.
A pinion consisting of two plates of brass or wood connected by cylindrical wires or trundles. Pages 77, 180.

Leaf, Aile, Zahn des Triebes.
The teeth of pinions are called leaves. Pages 107, 177–180.

Lever escapement, Echappement à ancre, die Ankerhemmung.
An escapement in which the connection between the escape wheel and the rollers on the balance staff is made by means of a detached lever. Pages 107–113, 181, 225, 234, 235, 238, 275.

Mainspring, Ressort moteur, die Zugfeder.
A long ribbon of steel used to supply the power for driving a clock or watch. Pages 103–105, 121, 173, 174, 229, 230, 269.

Maintaining power, Entretien, das Gegengesperr.
A device for driving a watch or clock while being wound. Pages 174–175, 230, 231, 262, 269, 292.

Maltese cross, Croix de Malte, das Malteserkreuz.
The star wheel used in stop work in connection with the ordinary going barrel. Pages 174–177, 202, 230, 231.

Mesh, Engrenage.
The engagement or interlocking of a set of gear-teeth of one wheel with those of another.

Motion work, Minuterie, das Zeigerwerk.
The wheels used for causing the hour hand to travel twelve times slower than the minute hand. Also called under-the-dial mechanism or the dial train. Pages 79, 113, 114, 195, 196, 238, 272, 294.

Movement, Mouvement, das Werk der Uhr.
The term applied to the works of a clock or watch as distinct from the case. Page 97.

Overcoil, Coudé.
The last coil of a Bréguet hairspring which is carried up and over the rest of the spring. Page 233.

Pallet, Ancre, die Palette.
That portion of the escapement which transmits the impulse to the balance or pendulum. Pages 107–113, 181–187.

Pawl.
Another name for a dog, click, or ratchet.

Pendulum, le pendule, das Pendel.
A body suspended from a fixed point so as to swing freely. Pages 77, 147, 182–194, 262.

Pendulum spring, Ressort de suspension, die Aufhängungsfeder.
The ribbon of steel used to suspend the pendulum of a clock. Page 190.

Pillar, Pilier, der Pfeiler.
Posts of brass for keeping the plates of a watch in a fixed position as regards each other. Pages 99, 240.

Pinion, Pignon, das Trieb.
The smaller of two toothed wheels which are geared into one another. The larger is called the wheel. Pages 75, 76, 106, 107, 177–185, 230–232, 269.

Pivot, Pivot, der Zapfen.
The end of an axle or arbor which rests in a support. Pages 76, 106, 107, 178, 231, 232, 269.

Ratchet, Rochet, das Sperrad.
A small lever which engages the teeth of a ratchet wheel and prevents it from turning backwards. Pages 75, 83, 104, 105, 229.

Remontoir, Force constante, die Hemmung mit constanter Kraft.
A contrivance consisting of a spring or other device which is wound up at frequent intervals by the driving power and which in turn imparts the impulses to the balance or pendulum.

Repeater, Montre à répétition, die Repetieruhr.
A watch or clock which indicates the time by striking on gongs or bells as often as one may desire. Pages 206, 244–247.

Safety pinion.
A center pinion which allows the barrel to recoil if the mainspring breaks. Page 106.

Snail, Limaçon, die Staffel.
A cam resembling a snail in shape, used mostly in the striking attachment to clocks. Pages 197, 202–206, 245, 246, 295, 442.
Snailing, Adoucissage en colimaçon, der Sonnenschliff.
Decorating a metal surface with rings, bars, etc. It is usually called damaskeening. Page 101.
Spandrels.
The decorated corners outside the dial. Pages 154, 195.
Stackfreed.
An eccentric cam used in early watches before the fusee for equalizing the pull of the mainspring. Pages 125, 230.
Staff, Axe, die Welle.
Another name for arbor or axle.
Stop work, Arrêtage, die Stellung.
An arrangement which prevents winding a mainspring too tight. Pages 174–177, 202, 230, 231, 269, 441.
Stud, Piton.
Any piece of metal, rod, or roller which projects from a part of the mechanism. It is used particularly for the small slotted piece of metal which holds the outer end of the balance spring. Page 109.

Three-quarter plate, Trois quarts de platine, das Dreiviertelplatinenwerk.
A watch in which part of the upper plate has been done away with. The balance has usually been placed on a level with the plate. Pages 99–103.
Tourbillon, Tourbillon, das Tourbillon.
A framework in which the escapement is fitted and which revolves around the fourth wheel. It was invented by Bréguet and is supposed to eliminate some of the position errors. Page 239.
Train, Rouage, das Laufwerk.
A series of wheels and pinions connecting the driving and controlling mechanism in a timekeeper. Pages 76, 178, 231, 232, 269, 322.

Under-the-dial mechanism (see *motion work*).
Up-and-down indicator, Indicateur de haut et bas, das Auf- und Abwerk.
A small dial for indicating how long a watch or chronometer will run before running down. Pages 230, 231, 257, 269.

Verge, Verge, die Spindel.
That part of the escapement which allows one tooth of the escape wheel to pass at a time. Pages 60, 77–79, 83, 84, 88, 92, 123, 163, 458.

Watch, Montre, die Taschenuhr.
A small portable pocket timekeeper. Pages 97–120.
Works.
The movement of a watch or clock as distinguished from the case. Page 97.

APPENDIX III

MUSEUMS AND COLLECTIONS

The perusal of the pages of this book may have created in the reader a desire to see old and unusual clocks and watches. The first natural question is where such collections of timekeepers may be seen.

There are two kinds of collections, public and private. The public collections are in museums and are, of course, accessible to the public. There are a few museums which have many old and interesting clocks and watches, but in most museums there are only a few examples. There are very many private collections, some of them extremely large, and these are of course not accessible to the public. As a rough estimate there are perhaps a hundred times as many old and interesting clocks and watches in private collections as in public museums. The private collections are also constantly changing. At the death of the owner the collection is sometimes bequeathed to a museum, very often it passes as a whole into the possession of some relative, and again it is scattered by sale.

It might also be an interesting question to ask how many examples are required to constitute a collection. There are thousands of individuals who possess one or two or a very few specimens, but they would hardly be considered to have a collection. To be considered a collection the number of examples should run up into the tens at least and perhaps into the hundreds.

In the United States the Metropolitan Museum of Art in New York City has by far the largest collection of watches in this country and probably the largest in the world. Lately the George A. Hearn collection has been bequeathed to the museum. This collection is described in a booklet entitled, *Collection of Watches loaned to the Metropolitan Museum of Art of the City of New York by Mrs. George A. Hearn.* The booklet was printed privately in 1907 but is obtainable from the Museum.

The J. P. Morgan collection of watches, which is probably the finest in the world and was for a long time a "loan exhibit" is now also the property of the Museum. A large part of this collection is made up of the F. Hilton Price collection (English) and the Carl Marfels collection (German) which were acquired by purchase. The Morgan collection has been written up in book form. The author is G. C. Williamson and the book is entitled, *Catalogue of the J. P. Morgan collection of Watches.* It is a large magnificent volume containing more than 300 pages and superb illustrations of the watches. It also contains a brief history of timekeepers in general and a short bibliography. There are also many other smaller collections which have been bequeathed to the Museum or are there as "loan exhibits." Among the later may be mentioned one by Maurice M. Sternberger which contains some very interesting and

valuable watches. Altogether there are some 500 on exhibition. There is also a good collection of sun-dials. There are a very few brass table clocks, a few grandfather clocks, but practically no American antiques, or French clocks.

The Boston Museum of Fine Arts also has a good collection of watches and there are a few clocks. The clocks are American grandfather clocks and the Massachusetts form of shelf clocks. Mention should also be made of the National Museum at Washington and the Pennsylvania Museum at Philadelphia. At the National Museum in Washington there are several hundred watches on exhibition, but they are nearly all early examples of American watches. There is also a fine collection of modern sun-dials and a few old ones.

The H. J. Heinz collection of watches is in the Carnegie Museum at Pittsburg. There is a "Catalog of the collection of watches belonging to Mr. H. J. Heinz jointly prepared by Douglas Stuart, W. J. Holland, and A. S. Coggeshall."

Essex Institute in Salem, Mass., now possesses a very fine collection of clocks. It was recently much enriched by the addition of the Charles Mifflin Hammond collection of 182 clocks and watches. Mr. Hammond was born in Boston in 1860 and died in 1916. He was an ardent clock collector during nearly his whole life. In accordance with a request made just before his death, Mrs. Hammond in 1918 gave the clock collection to the Essex Institute where they are assigned to a specially constructed room. They are in large part American antique clocks of all kinds.

Among the private collections in this country the following may be mentioned: Mr. Kelley, Mr. Henry M. Ney, Mr. Frederick T. Proctor, and Mr. Thomas R. Proctor, all of Utica, N.Y., have good collections of watches. The Frederick T. Proctor collection has been written up in book form. It is entitled *The F. T. Proctor Collection of antique Watches and Table Clocks* and was published at Utica in 1913. It contains many excellent illustrations. Mr. Paul M. Chamberlain of Chicago also has a collection of watches. Mr. Moulton of Newburyport, Mass., has a fine collection of Dutch clocks which were procured for the most part in Holland. Mrs. Harriett Brownell of Newport and Providence has a big collection containing many fine examples of early American clocks. Mr. L. C. Flynt of Munson, near Springfield, Mass,, has an immense collection of more than 400 early American clocks. His specimens by early Connecticut clockmakers are superb. Mr. William F. Lucas, Jr., of Baltimore, Md., has a fine collection of French clocks of the period from about 1750 to 1820 and Mr. Philip L. Spalding of Boston, Mass., has a superb collection of Simon Willard clocks. Another good clock collection is that of Mr. Edgar G. Miller, Jr., of Baltimore, Md.

Miss Mary Harrod Northend, 209 A Washington St., Salem, Mass., has among her 20,000 to 30,000 photographs quite a number of "antique" clocks. These photographs are for sale and at a reasonable price.

In London, the British Museum, the South Kensington Museum (Victoria and Albert Museum), the Museum of the Clockmakers' Company in the Guildhall, and Hertford House (the Wallace collection) in Manchester Square all have magnificent collections of both watches and

clocks. The British Museum and the South Kensington Museum have by far the most watches. The Wallace collection is richest in French clocks and the South Kensington Museum is richest in English grandfather clocks. No one of them has a large collection of English grandfather clocks. In fact one can see more grandfather clocks in the sales rooms of Percy Webster, 37 Great Portland St., than in any museum in London.

Outside of London the Royal Scottish Museum at Edinburgh, the Fitzwilliam Museum at Cambridge, and the Ashmolean Museum at Oxford are the most noted for their collections of watches and clocks. In Edinburgh there are about thirty or forty watches (some of them very famous), a few grandfather clocks, and a few French clocks. At Cambridge there are a hundred or more watches and a few clocks. There is a catalogue of the timekeepers in the Guildhall Museum and also a catalogue of the famous collection of the Rev. H. L. Nelthropp which is now in the Guildhall. There is also a *Catalogue of the clocks, etc., in the Wallace collection* (8vo, 404 pp., London, Hertford House, 1905).

Among the big private collections in England may be mentioned that of Percy Webster and his son Malcolm R. Webster, the Wetherfield collection of clocks, and the collection of watches by Franklin Dennison of Leamington. The Wetherfield collection of clocks is one of the finest in the world and contains over 200 examples, affording a perfect historical review of English clockmaking from 1675 to 1775. It has been written up in book form. The handsome volume containing many illustrations is by F. J. Britten and it is entitled *Old English Clocks* (*the Wetherfield Collection*) and published by Lawrence and Jellicoe, London, 1907.

Other well-known collections which are often spoken of are the Evan Roberts collection, the Albert Schloss collection, the Hawkins collection, the T. W. Bourne collection, the T. Whitcombe Greene collection, the E. Alfred Jones collection, the R. Norman Shaw collection, the R. Eden Dickson collection, the Mainwaring collection, the Thomas Boynton collection, the Ponsonby collection, the J. D. Robertson collection, and the Dunn Gardner collection. It must be remembered, however, that private collections are constantly changing. For example, the Evan Roberts collection of watches which was usually spoken of as the most extensive in the world, either public or private, has been dispersed, a large part going to Mr. Franklin Dennison. Albert Schloss died some ten years ago and his collection has been scattered. The Hawkins collection was dispersed by auction in 1890. The E. Alfred Jones collection is new at the South Kensington Museum. The R. Norman Shaw collection was sold at Christie's. The T. W. Bourne collection, the Mainwaring collection, and the Dunn Gardner collection have been scattered.

There are about 300 clocks in Windsor Castle collected in large part by Queen Victoria, 175 in Buckingham Palace, and 100 in Hampton Court Palace. Some of these are seen when the castles are visited.

In France there is a magnificent collection of both watches and clocks at the Louvre in Paris. The private collection of Paul Garnier was usually spoken of as the most complete in France. Most of this was given to the Louvre in 1916, and these watches added to those already

at the Louvre have made the collection at this museum a very good one. More than a hundred are on exhibition. There is a handsome illustrated *catalogue de la collection Paul Garnier* published by Librairie Hachette & Cie in 1917 which may be purchased at the Louvre. There is also a good collection of clocks, particularly cartel and mantel clocks, at the Louvre. There are also many watches, clocks, and chronometers at the Conservatoire des Arts et Métiers in Paris, but this collection is primarily for those who are interested in the movement rather than the case. Many fine French clocks are also to be seen at the Musée Carnavalet, at the Musée du Garde Meuble, at the Musée de Cluny, and at the palaces of Versailles and Fontainebleau near Paris.

At Besançon and Lyons there are also collections worthy of note. At the Museum of Lyons there are some twenty watches, two or three table clocks, and a few French clocks. There is an illustrated catalogue by Claudius Cote entitled *Montres et Horloges* which may be purchased at the museum.

In Switzerland the private collection of Mr. G. Loup of Geneva is very extensive. This has been exhibited twice. At present about thirty-five watches from this collection are exhibited at the Musée d'Art et d'Histoire in Geneva. They are fine examples and date from 1780 to 1820. These added to the watches already in the museum have formed a good collection of more than a hundred.

In Italy one is struck by the absence of watches and clocks in the museums. Even Roman sun-dials, although said to have been so common, are never seen.

In Germany and Austria there are many museums in different cities which have good collections, particularly of German table clocks. Among these may be mentioned the Kunstgewerbe-Museum at Berlin, the Bayerisches National-Museum at Munich, the Oesterreichisches Museum für Kunst und Industrie and also the Kunsthistorisches Hof-Museum at Vienna, the Museum Carolino-Augusteum at Salzburg, the Germanishes Museum at Nürnberg, the Kgl. Mathematisch-Physikalischer Salon in Dresden, the Grünes Gewölbe or Treasury of the Palace in Dresden, and the Maximillian Museum at Augsburg.

The private collection of E. Bassermann-Jordan of Munich is also extensive. The N. R. Frankel collection of watches has been written up in book form by Heinrich Frauberger. The title is, *N. R. Frankel's Uhrensammlung* and the book was published in Düsseldorf in 1913. The famous Carl Marfels collection has ceased to exist as it was purchased by Mr. J. P. Morgan and has become a part of the Morgan collection. Carl Marfels was traveling representative of a firm dealing in watch material. In this way he became interested in old watches and began collecting. In 1909 about 40 watches were sold to J. Pierpont Morgan for \$150,000 and in 1910 about 40 more were sold for \$225,000. This collection was described in a book by Gustav Speckhart entitled, *Kunstvolle Taschenuhren der Sammlung Marfels* and published in 1904.

The Czar of Russia had about fifty watches in the Winter Palace in Petrograd. These have been described by E. Alfred Jones in an article in the *Connaisseur*. The famous Pierre Soltykoff collection has been described in detail by Pierre Dubois. The book is entitled, *Collection*

archéologique du Prince Pierre Soltykoff. It was published in Paris in 1858. This famous collection was scattered in 1861. A considerable part of it was acquired by M. Paul Garnier and thus many of the watches have eventually come into the possession of the Louvre in Paris.

Abbott in his book *Antique Watches and how to Establish their Age* published in Chicago in 1897 has this to say about collections:

"The custom of collecting watches and clocks of antique make, and rare or beautiful forms, appears to be of no recent date. Public and private collections abound in every civilized country, but the private collections, where they are of any extent, are owned by people of means. The largest collection of watches in the world, public or private, is owned by Mr. Evan Roberts, of London, and it embraces some of the finest examples extant. The collection owned by Mr. Carl Marfels, of Berlin, while not as extensive as Mr. Roberts', is probably the most perfect, from a chronological point of view, in existence. The collection of Prince Pierre Soltykoff, from an archeological standpoint, is extremely valuable and embraces some of the most exquisite examples of the horological art both in clocks and watches. It is particularly rich in the magnificent examples of early 16th century watches in rock crystal cases and in rare specimens of pieced and engraved cases. Among the notable English collections, both public and private, I must not fail to mention those of the British and South Kensington museums, the Society of Antiquaries, the Clockmakers' Company, that of the Rev. H. L. Nelthropp, Mr. T. Whitcombe Greene, Mr. J. Keane, Mr. J. F. Kendal, Mr. Percy Webster, Messrs. Wells Bros., and Landsberg & Sons. The public museums of Germany and Bavaria contain many fine collections. The most complete collection in France is said to be that owned by Mr. Paul Garnier, of Paris, and the finest in Italy that of Mr. Amerigo Ponti, of Milan. In America, the finest collections are owned by private parties, although there is an interesting collection in the museum of the Smithsonian Institution, Washington. Mr. Vanderbilt, Mr. Havemeyer and Mr. Simpson, New York, have very valuable collections. The late Mr. Childs, Philadelphia, possessed the finest collection of clocks in this country. The collections of Messrs. Ney and Kelley, Utica, N.Y., contain many fine specimens. Besides the people enumerated above there are thousands of persons who have small collections consisting of from ten to twenty-five specimens."

The excellent book *Time Telling through the Ages* by Harry C. Brearley, published by Doubleday, Page & Co. (1920), for Robert H. Ingersoll & Bro., contains an appendix in which is given a list of well-known watch collections prepared by Paul M. Chamberlain, himself a collector, of 427 Diversey Parkway, Chicago, Ill. The collections listed (both public and private) number 123. Of these 13 are private American collections.

If the index of Britten's magnificent book *Old Clocks and Watches and their Makers* (preface of the last edition dated 1922) is consulted, the names of several hundred individuals will be found who have or who have had collections.

There are thirty-two collections which are mentioned five or more times. The following list contains the names and the small figure denotes the number of times each collection is mentioned: Bernal ^{5}; T. W.

Bourne [10]; T. Boynton [10]; R. E. Dickson [11]; Dunn Gardner [16]; Fellows [5]; Garnier [26]; E. Gélis [16]; G. C. Glyn [14]; Hawkins [8]; H. J. Heinz [9]; Hilton Price [7]; J. E. Hodgkin [12]; Jones [9]; Marfels [9]; J. M. Moody [7]; Morgan [92]; W. R. Moss [5]; Nelthropp [21]; Ponsonby [23]; Evan Roberts [27]; J. D. Robertson [21]; Schloss [74]; Shandon [9]; Norman Shaw [12]; Soltykoff [24]; Duke of Sussex [11]; Wallace [22]; Watt Hansard [29]; Wetherfield [114]; N. H. Wheeler [6]; Whitcombe Green [6].

A list of the principal collections, past and present, compiled by Paul M. Chamberlain is contained in the *Jewelers' Circular*, August to December, 1915.

APPENDIX IV

THE CONVERSION OF TIME

The interrelations of the four different kinds of time and the methods of computing the others when one is given, can best be illustrated by means of a numerical example.

> *If on November* 1, 1922, *at Williamstown, Mass., longitude* $4^h52^m50^s$ *west of Greenwich, the eastern standard time is* 8 P.M., *what are the corresponding mean solar time, true solar time, and sidereal time?*

Since Williamstown is in the eastern standard time belt, its time is exactly 5 hours slower than Greenwich mean solar time. The longitude is $4^h52^m50^s$ and thus the timekeepers ought to run only this much slower than Greenwich time. The timekeepers are therefore run 7^m10^s (time hour of belt minus longitude) slower than they would be if they were keeping the mean solar time of the place. Thus if the eastern standard time is 8 P.M., the mean solar time is $8^h7^m10^s$

Rule for any place:

> *Subtract the longitude from the time hour of the belt and add the difference (taking account of the algebraic sign) to the standard time to get mean solar time or subtract it from mean solar to get standard.*

True or apparent solar time may now be found. On page 14 of the *American Ephemeris and Nautical Almanac* for 1922 the value of the equation of time (in the sense of apparent time minus mean time) for the various dates near November 1 may be found. These values are tabulated below and the differences are found by subtracting down.

Date	Equation of Time	1st Difference	2nd Difference
Oct. 31, 1922	$+16^m16.37^s$		
		$+2.36^s$	
Nov. 1	$+16^m18.73^s$		-0.79^s
		$+1.57^s$	
2	$+16^m20.30^s$		-0.80^s
		$+0.77^s$	
3	$+16^m21.07^s$		-0.80^s
		-0.03^s	
4	$+16^m21.04^s$		

These values of the equation of time are for Greenwich mean noon. When it is 8 P.M. eastern standard time, the time in Greenwich is 13 past mean noon. The exact value of the equation of time for 13 past

noon on Nov. 1 must thus be found by interpolation. The best interpolation formula to use is probably:

$$\text{Value} = F + n\tfrac{1}{2}(a_1 + a^1) + \frac{n^2}{2}\, b + \frac{(n+1)n(n-1)}{2.3}\,\tfrac{1}{2}(c_1 + c^1) + \ldots$$

Here F is $+\ 16^m 18.73^s$; a_1 is $+\ 2.36^s$; a^1 is $+\ 1.57^s$; b is $-\ 0.79^s$; n is $\frac{13}{24}$. c_1, c^1, and higher terms do not exist.

Therefore the value of the equation of time for 8 P.M. eastern standard time is:

$$\begin{array}{r} +\ 16^m 18.73^s \\ +\ 1.06^s \\ -\ 0.12^s \\ \hline +\ 16^m 19.67^s \end{array}$$

The true solar time is thus $8^h 7^m 10^s$ plus $16^m 19.67^s$ or $8^h 23^m 29.67^s$.

If the value of the equation of time is desired only to the tenth of a second, it may be computed much more quickly by another method. Since this accuracy is all that is desired in Navigation, it is always computed in navigation problems in the following manner: In the *American Ephemeris* in the column next to the value of the equation of time is given the so-called hourly change in these values. It is nothing more or less than $\frac{1}{24} \cdot \frac{1}{2}\,(a_1 + a^1)$. Thus the shorter method of computing the equation of time is as follows: Multiply the hourly change by the number of hours since Greenwich mean noon and add it algebraically, taking account of the sign, to the value of the equation of time for mean noon. In the present example the hourly change, taken from the *American Ephemeris*, is $+\ 0.082^s$.

$$+\ 0.082^s \times 13 = +\ 1.07^s$$

The equation of time is thus

$$16^m 18.73^s + 1.07^s = 16^m 19.80^s$$

This differs by 0.13^s from the correct value $+\ 16^m 19.67^s$ which was obtained by exact interpolation, but is sufficiently accurate for navigation purposes.

To find the sidereal time the same table on page 14 of the *American Ephemeris* for 1922 must be used. It is there stated that the sidereal time of the mean sun (i.e., mean noon) at Greenwich on November 1 is $14^h 39^m 57.42^s$. While the sun is coming from the meridian of Greenwich to the meridian of Williamstown, $4^h 52^m 50^s$ elapse, and during this interval, sidereal time has gained over solar 48.10^s. (On page 697 of the *American Ephemeris* see tabular value corresponding to $4^h 52^m 50^s$.) The sidereal time of mean noon at Williamstown is thus $14^h 39^m 57.42^s$ plus 48.10^s or $14^h 40^m 40.52^s$. But the sidereal time is required for $8^h 7^m 10^s$ after mean noon. This interval of solar time must thus be changed into sidereal and added to the $14^h 40^m 45.52^s$. Using the table on page 698 of the *American Ephemeris* we thus have:

$$\begin{array}{r} 14^h 40^m 45.52^s \\ 8^h\ \ 7^m 10^s. \\ 1^m 20.03^s \\ \hline 22^h 49^m 15.55^s \end{array}$$

This is the corresponding sidereal time.

Thus finally:

Nov. 1, 1922, Williamstown, Mass., long. $4^h52^m50^s$		
8^h P.M.	eastern standard time	
$8^h\ 7^m10^s$	mean solar or local time	are one and the same.
$8^h23^m29.67^s$	true or apparent solar time	
$22^h49^m15.55^s$	sidereal time	

* * * *

By similar computations any kind of time may be changed to any other kind of time at the same place.

* * * *

Another time problem which often arises is to change from a given kind of time at *one place* to the same kind of time at *another place*. If it is standard time that is being changed then the difference in time between the two places is the difference in the time hours of the belts in which the two places are located. If it is true solar time, mean solar time, or sidereal time that is being changed then the difference in time between the two places is the difference in their longitudes.

Example 1:

If it is 3 P.M. eastern standard time in New York, what is the standard time in Denver?

Denver is in the mountain time belt and New York is in the eastern time belt. The difference is thus 2 hours. It is thus 1 P.M. in Denver by mountain standard time.

Example 2:

If it is $9^h10^m10^s$ sidereal time in Williamstown, long. $4^h52^m50^s$, what is the sidereal time in New Orleans, long. $6^h0^m14^s$?

The difference in longitude is $1^h7^m24^s$. The sidereal time in New Orleans is thus $8^h2^m46^s$.

* * * *

The *general* time problem is to change from a given kind of time at one place to another kind of time at a different place. The best way to do this is by way of Greenwich. Suppose the problem were to change from eastern standard time at Williamstown to sidereal time at Chicago. First change from eastern standard time at Williamstown to standard time or mean solar time at Greenwich (at Greenwich standard time and mean solar time are the same); then change from mean solar time at Greenwich to sidereal time at Greenwich; and finally change from sidereal time at Greenwich to sidereal time at Chicago. Three steps are thus required to solve the problem; two involve a change of place and one a change of time.

APPENDIX V

BIBLIOGRAPHY

(*A*) Time
(*B*) Sun-dial
(*C*) Clepsydra
(*D*) General list
  (1) For the general reader
  (2) For watchmakers and clockmakers
  (3) The general list reclassified
    (*a*) Illustrations of old clocks
    (*b*) Illustrations of old watches
    (*c*) Illustrations of old American clocks
    (*d*) Lists of clock and watch makers
    (*e*) Lists of American clockmakers
    (*f*) For collectors of clocks and watches
    (*g*) History of watchmaking and clockmaking in America
    (*h*) History of watchmaking and clockmaking in Europe
    (*i*) Biographical material
(*E*) Chronometers
(*F*) Modern tower clocks
(*G*) Electrical clocks
(*H*) Precision clocks
(*I*) Testing timekeepers and their accuracy
(*J*) Descriptions of famous individual clocks and watches
(*K*) The mathematics of horology
(*L*) Bells
(*M*) Bibliography
(*N*) Periodicals

On the following pages are listed about 500 books, pamphlets, and articles which deal with time and timekeepers. The attempt has been made to have the list fairly full and yet no claim can be laid to completeness. To list *all* the books, pamphlets, and articles from the beginning to the present time would require hundreds of pages. The material has been carefully classified under many different heads. It would be well to study carefully the classificaton as given on page 568 before attempting to look up the literature on any subject. In general the classification follows the order of the chapters in this book. The purpose of this bibliography is to point the way to the acquisition of more information, on the part of him who wishes it, than can be found in this book. The most important books in each class have sometimes been given one star and the especially good ones two stars. The first time a book is listed it is given a serial number and further information about the book such as size, number of pages, publisher, date, and the like is usually added. If the same book is again mentioned later, only the author and title are given. It does not get a new serial number but the old one is added in square brackets. By looking up this number the further information about the book may be found. In each group they are usually arranged in alphabetical order, not in order of age or importance.

The larger libraries in the larger cities will be found to contain a considerable number of these books and articles. Nearly every public library will contain a few, and often more than one would expect. According to the American Library Annual 1914–1915 the four largest libraries in the United States are the New York Public Library with 2,312,000 books; the Library of Congress at Washington with 2,253,000; the Boston Public Library with 1,098,000; and the Library of Yale University at New Haven with 1,000,000. The other libraries with more than a half million books are, Brooklyn Public Library with 808,000; the Library of Harvard University at Cambridge with 706,000; the New York Public School Library with 661,000; the Chicago Public Library with 598,000; the Library of Columbia University at New York with 574,000; the Public Library at Cleveland with 560,000; the Library of the University of Chicago with 532,000; and the Free Library of Philadelphia with 510,000. All of these libraries are of course growing rapidly each year.[1]

(*A*) TIME

The following treat of time in general and the different kinds of time:

(1) Accurate Time (a small advertising pamphlet put out by the Illinois Watch Co., Springfield, Ill.).

(2) Arthur, James, *Time and its Measurement.* 8vo, 64 pp., Chicago, 1909.

(3) *Encyclopaedia Britannica.* (All encyclopaedias of course contain something on time.)

(4) * Moulton, Forest Ray, *An Introduction to Astronomy* (new edition). 8vo, xxii + 577 pp., The Macmillan Co., New York, 1916.

[1] The New International Encyclopaedia, under the word "Library," contains a list of all libraries in the world with more than 250,000 books.

(5) Thomson, Adam, *Time and Timekeepers.* xii + 195 pp., London, 1842.
(6) Todd, David P., *A New Astronomy.* 8vo, 480 pp., American Book Co., New York, 1897.
(7) * Young, Charles A., *Manual of Astronomy.* 8vo, vii + 611 pp., Ginn & Co., New York, 1902 and 1909.

Practically every textbook or general treatise on Descriptive Astronomy treats of the various kinds of time. Only three of these have been listed above.

* * * *

The following treat of the methods of determining time by observation, the instruments used, and the methods of computing one kind of time from another. They are books for the Mathematician and Astronomer and not for the general reader.

(8) Ball, Robert, *A Treatise on Spherical Astronomy.* 8vo, xii + 506 pp., Cambridge, 1908.
(9) Brünnow, F., *Lehrbuch der sphärischen Astronomie.* 8vo, xvi + 587 pp., Berlin, 1881.
(10) * Campbell, W. W., *The Elements of Practical Astronomy.* 8vo, xii + 264 pp., 2d ed., The Macmillan Co., 1899.
(11) Caspari, E., *Cours d'Astronomie pratique.* 2 vols., xii + 276 and viii + 344 pp., Paris, 1888.
(12) ** Chauvenet, William, *A Manual of Spherical and Practical Astronomy.* 2 vols., 8vo, 708 and 632 pp., J. B. Lippincott & Co., Philadelphia, 1863.
[3] *Encyclopaedia Britannica.*
(13) * Comstock, George C., *Field Astronomy for Engineers.* 8vo, x + 202 pp., John Wiley & Sons, New York, 1902.
(14) De Ball, L., *Lehrbuch der sphärischen Astronomie.* Big 8vo, xv + 387 pp., Leipzig, 1912.
(15) Doolittle, C. L., *A Treatise on Practical Astronomy.* 8vo, x + 642 pp., John Wiley & Sons, New York, 1885.
(16) Greene, Dascom, *An Introduction to Spherical and Practical Astronomy.* 8vo, viii + 150 + 8 pp., Ginn & Co., Boston, 1891.
(17) Hayford, John F., *A Text-book on Geodetic Astronomy.* 8vo, ix + 351 pp., John Wiley & Sons, New York, 1898.
(18) Herr and Tinter, *Lehrbuch der sphärischen Astronomie.* 8vo, 644 pp., Wien, 1887.
(19) *Hosmer, George L., *Practical Astronomy.* 8vo, ix + 205 pp., John Wiley & Sons, New York, 1910.
(20) Loomis, Elias, *An Introduction to Practical Astronomy.* 8vo, xi + 498 pp., Harper & Brother, New York, 1855.
(21) Michie and Harlow, *Practical Astronomy.* 8vo, ix + 218 pp., John Wiley & Sons, New York, 1893.
(22) Newcomb, Simon, *A Compendium of Spherical Astronomy.* 8vo, xviii + 444 pp., The Macmillan Co., New York, 1906.
(23) Sears, Frederick Hanley, *Practical Astronomy for Engineers.* 4to, ix + 134 pp., Columbia, Missouri, 1909.
(24) Time Taking, Time Keeping (an advertising pamphlet issued by the Elgin National Watch Co. at Elgin, Ill.).

Practically every book on Spherical or Practical Astronomy treats of this subject. Only the best and more modern ones have been listed.

(*B*) SUN-DIAL

The following are the very oldest books which touch upon or treat the subject of sun-dials.

(25) VITRUVIUS, *De Architectura.* (Translated by Morgan, 1914.)
(26) PTOLEMY, *Almagest.*

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The following treat of sun-dials in general. They are all later than 1875.

(27) BILFINGER, G., *Die Zeitmesser der Antiken Völker.* Stuttgart, 1886.
(28) BRITTEN, F. J., *Old Clocks and Watches and Their Makers* (5th ed.). 8vo, xii + 822 pp., London, 1922. (Pages 5–9 treat of sun-dials.)
(29) DAWBARN, *The Sun-dial.* London, 1891.
(30) DYER, WALTER A., "Sun-dials in Modern Gardens." *Country Life in America*, March, 1906.
(31) * EARLE, ALICE MORSE, *Sun-dials and Roses of Yesterday.* 8vo, xxiii + 461 pp., New York, 1902.
[3] *Encyclopaedia Britannica.*
(32) * GATTY, MRS. ALFRED, *The Book of Sun-dials* (new and enlarged edition by H. K. F. Gatty and Eleanor Lloyd). 8vo, vii + 502 pp., London, 1889.
(33) HENSLOW, THOMAS GEOFFREY WALL, *Ye Sun-dial Booke.* 8vo, 422 pp., London, 1914.
(34) HOGG, WARRINGTON, *The Book of Old Sun-dials — Their Mottoes.* London, 1917.
(35) * JACOBY, HAROLD, *Astronomy.* 8vo, xiii + 435 pp., New York, 1913. (Chapter V treats of the sun-dial.)
(36) * LÖSCHNER, HANS, *Sonnenuhren.* 8vo, 154 pp., Graz, 1905.
(37) SCHULTZ, W., *Die Zeitmesser des Altertums bis zur Erfindung des Pendels.* Berlin, 1893.
(38) SOUCHON, ABEL, *La construction des cadrans solaires.* 8vo, viii + 52 pp., Paris, 1905.
(39) * SPACKMAN, HENRY SPENCER, *The Timepiece of Shadows, a History of the Sun-dial.* ii + 110 pp., New York, 1895.

* * * *

The following contain many of the mottoes which have been placed on sun-dials.

[32] * GATTY, MRS. ALFRED, *The Book of Sun-dials.*
[33] HENSLOW, T. GEOFFREY W., *Ye Sun-dial Booke.*
[34] * HOGG, WARRINGTON, *The Book of Old Sun-dials — Their Mottoes.*
(40) * HYATT, ALFRED H., *Book of Sun-dial Mottoes.* 16mo, xvi + 123 pp., London, 1903.
(41) * RAWLINGS, ALFRED, *Book of Sun-dials and Their Mottoes.* 8vo, 116 pp., 1915.

[39] SPACKMAN, HENRY SPENCER, *The Timepiece of Shadows.*

* * * *

The following treat of dialing or the art of making a sun-dial. They have been divided into two groups—(group I) those which the amateur could probably use for constructing a sun-dial, and (group II) those which could probably not be used unless one were fairly familiar with Mathematics and accustomed to reading old books. The list is far from complete. If complete there would be nearly 100 entries. Those listed are either the largest, or the best, or the easiest to understand, or those usually found in libraries.

Group I

(42) * *Annuaire du Bureau des Longitudes, annees* 1904, 1906, 1918, 1920, 1921. The last three articles are by G. Bigourdan and are entitled *Les cadrans solaires.*

(43) BOUTEREAU, C., *Nouveau manuel complet de gnomonique élémentaire.* 18mo, 318 pp., Paris, 1845.

(44) BROWN, F. WILLARD, "A Simple Method of Laying Out a Sun-dial." *Scientific American,* vol. 101, page 355.

(45) CELLES, F. BEDOS DE, *La gnomique pratique, ou l'art de tracer les cadrans solaires.* 8vo, 426 pp., Paris, 1760 (2d ed. enlarged 1874).

(46) DOUGLAS, E. M., "Sun-dials, how they are made and used." *Scientific American,* vol. 98, page 425.

[32] * GATTY, MRS. ALFRED, *The Book of Sun-dials.*

(47) HIRSBERG, LEONARD K., "A Pocket Sun-dial." *Scientific American,* vol. 107, page 120, Aug. 10, 1912.

(48) ** JACOBY, HAROLD, *Practical Talks by an Astronomer.* 8vo, ix + 235 pp., New York, 1902. (Pages 69–80, How to make a sun-dial.)

(49) LITTROW, J. J., *Gnomonik, oder Anleitung zur Verfertigung aller Arten von Sonnenuhren.* 8vo, Wien, 1831 (2d ed. 1839).

(50) OZANAM, J., *Traité de gnomonique pour la construction des cadrans sur toutes sortes de plans.* 12mo, Paris, 1673. (Reprinted with additions, 8vo, Paris, 1746.)

(51) STERNHEIM, H., *Populäre Gnomonik.* 8vo, Weimar, 1835.

[39] SPACKMAN, *The Timepiece of Shadows.*

Group II

(52) BORN, *Gnomonique graphique et analytique.* 8vo, Paris, 1846.

(58) CLAVIUS, *Gnomonices de Horologiis.* 1612. (One of the largest of the seventeenth century books.)

(54) FALE, THOMAS, *Horologiographia.* The art of dialing, etc. Printed in London in 1593. (This was the first work on dialing in English.)

(55) FERCHEL, J., *Praktische Sonnenuhren-Kunst für jedermann.* 8vo, Passau, 1849.

(56) FERGUSON, JAMES, *Select Mechanical Exercises, showing how to construct Different Clocks, Orreries, and Sun-dials.* 10 + 43 + 272 pp., London, 1778.

(57) FOSTER, SAMUEL, *the Art of Dialling; by a new, easie, and most speedy way.* 39 pp., Printed in London in 1638.

(58) *Garnier, J. B., *Gnomonique mise a la portée de tout le monde.* 8vo, Paris, 1773.
(59) Leadbetter, *Mechanick, Dialling.* 3d ed., 1769.
(60) *Leybourn, William, *Dialing.* 4to, 330 pp., London, 1682. (Hard reading but one of the best.)
(61) Mollet, Joseph, *Gnomonique graphique.* 8vo, 123 pp., Paris, 1827 (7th ed., 1884).
(62) Münster, Sebastian, *Horologiographia.* 4vo, 56 + 334 pp., Basel, 1533.
(63) *Sonndorfer, Rudolf, *Theorie und construction der Sonnen-Uhren.* 5 + 92 pp., Wien, 1864.
(64) Wells, John, *Sciographia, or the Art of Shadowes.* 8vo, 427 pp., London, 1635.

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The literature on sun-dials is large. A complete list of the books and articles would probably contain about 300 entries. Löschner, in his *Sonnenuhren*, lists 77. The last edition of the Encyclopaedia Britannica mentions some 36. In the *Bibliographie générale de l'Astronomie* by Houzeau and Lancaster about 100 articles previous to 1882 are listed (in §34 under gnomonique). In the *Vade-mecum de l'Astronomie* by Houzeau 47 books previous to 1882 are listed (§78, page 158). In J. Alexandre, *Traité général des horloges* (8vo, Paris, 1734) will be found a catalogue of the older writers. For the very recent scientific literature see the *International Catalogue of Scientific Literature, section E*, which starts with 1901, or the *Astronomischer Jahresbericht* which starts with the literature of 1899. In each case one volume a year is published. For popular magazine articles consult the indices of Poole, Fletcher, and Readers' Guide.

These will serve as good starting points for any who might like to look up the entire literature on sun-dials. The big libraries in the larger cities will usually contain from 10 to perhaps nearly 100 of these articles and books on sun-dials.

(*C*) CLEPSYDRA

The following books contain a few pages on clepsydras.

[2] Arthur, James, *Time and its Measurement.*
[27] Bilfinger, *Die Zeitmesser der antiken Völker.*
[28] Britten, F. J., *Old Clocks and Watches and Their Makers.*
(65) Cunynghame, H. H., *Time and Clocks.* 8vo, 200 pp., New York, 1906.
[3] *Encyclopaedia Britannica.*
(66) Nuttall, G. C., "Water Clocks B.C. and A.D." *Gent. M.*, n.s., 59.
[25] Vitruvius, *De Architectura.*

(*D*) GENERAL LIST

The general list contains books, pamphlets, and articles which deal with time and timekeepers in general. It has been divided into three parts. The first group contains the material which is of chief interest to

the general reader. The second group contains the material which is of chief interest to watchmakers and clockmakers. These two groups do not overlap. In the third group, which consists of the nine lists (a) to (i), the material of the general list has been reclassified. No new material has been added.

(1) FOR THE GENERAL READER

(67) ** Abbott, Henry G., *The Watch Factories of America, past and present.* 8vo, 144 pp., Chicago (G. K. Hazlitt & Co.), 1888.

(68) ** Abbott, Henry G., *Antique Watches and How to Establish their Age.* 12mo, 204 pp., Chicago, 1897.

(69) ** Abbott, Henry G., *History of the American Waltham Watch Company* (reprinted and revised from the Watch Factories of America). 8vo, 109 p., Chicago, 1905.

(70) Alléaume, Auguste, *Les Brevets d'Invention (francais) concernant l'Horlogerie* (1792–1869). 8vo, 144 pp., 1873.

(71) * Ambronn, *Handbuch der astronomischen Instrumentenkunde.* 2 vols., 4to, ix + 500 pp. and vii + 776 pp., Berlin, 1899. (Vol. I, pages 161–278 on Timekeepers.)

(72) "Ancient Clock-Jacks." *Scientific American Supplement*, vol. 85, p. 145, March 9, 1918.

[2] * Arthur, James, *Time and Its Measurement.* 8vo, 13 + 64 pp., Chicago, 1909.

(73) * Atkins, S. E. and Overall, W. H., *Some Account of Worshipful Company of Clockmakers of the City of London.* 4to, xvii + v + 346 pp., London, 1881.

(74) Babel, Antony, *Histoire Corporative de l'Horlogerie.* 8vo, 606 pp., Geneva, 1916.

(75) Baden (Ministerium des Innern), *Organisation der Uhrenmacherschule in Furtwangen.* 8vo, 44 pp., 1858.

(76) *Bailey, Roy Rutherford, *Through the Ages with Father Time.* 8vo, 192 pp., 1922.

(77) Barfuss, F. W., *Geschichte der Uhrmacherkunst.* 3d ed., 12mo, 386 pp., Weimar, 1856. (4th ed. in 1887; 5th ed. revised by Gelcich in 1892.)

(78) Bassermann-Jordan, *Die Geschichte der Räderuhr.* Folio, ii+113 pp., Frankfurt, 1905.

(79) * Bassermann-Jordan, *Uhren: ein Handbuch für Sammler und Liebhaber.* 8vo, viii + 156 pp., Berlin, 1914.

(80) Beillard, Alfred, *Recherches sur l'Horlogerie, ses Inventions et ses Célébrités.* 8vo, viii + 207 pp., Paris, 1895.

(81) * Beillard, Alfred, *La Montre depuis son origine jusqu'à nos jours.* 8vo, 153 pp., Paris, 1907.

(82) Belgrano, *Antiqui Orologi d'Italia.*

(83) Benson, James W., *Time and Time-tellers.* 8vo, vii + 189 pp., London, 1875 (reprinted 1902).

(84) Berthoud, Ferdinand, *Essai sur l'Horlogerie.* 3 vols. (1st ed., 1763), 2d ed., Paris, 1786.

(85) Berthoud, Ferdinand, *Histoire de la Mesure du Temps par les Horloges.* 2 vols., 4to, Paris, 1802.

(86) Bock, H., *Die Uhr, Grundlagen und Technik der Zeitmessung.* 8vo, 136 pp., Leipzig, 1908 (2d ed., 121 pp., 1917).
(87) Borle, Henri, *Les Transformations industrielles dans l'Horlogerie Suisse*, 1910.
(88) ** Bouasse, Henri, *Pendule, Spiral, Diapason.* 8vo, 2 vols., xxvi + 474 pp. and xxii + 518 pp., Paris, 1920.
(89) Brassler, Charles A., "Antique Watches of the Famous Marfels Collection." *Scientific American*, vol. 92, pp. 165–6 (Feb. 25, 1905).
(90) Brassler, Charles A., "Finest Collection of Antique Watches in the World." *American Homes*, 7, 275–7 (July, 1910).
(91) * Brearley, Harry C., *Time Telling through the Ages.* 8vo, 294 pp. (Published by Doubleday, Page & Co. for Robert H. Ingersoll and Bro.), 1919.
(92) Britten, Frederick James, *Former Clock and Watchmakers and Their Work.* 8vo, 8 + 397 pp., London, 1894.
(93) Britten, Frederick James, "Old Long Case Clocks." *International Studio*, vol. 17, pp. 188–189 (Sept., 1902).
[28] ** Britten, Frederick James, *Old Clocks and Watches and Their Makers.* 8vo, viii + 790 pp., 3d ed., London (B. T. Batsford), 1911. (1st ed., viii + 500 pp., London, 1899.) New 5th ed., 8vo, xii + 822 pp., London, 1922.
(94) * Caspari, C. E., "Theorie der Uhren." *Encykl. d. math. Wiss.*, vol. 6, part 2, fascicle 1, 163–193.
(95) *(Caspari, C. Ed., "Les horloges." *Encyclopédie des Sciences mathématiques pures et appliquées*, 7_5, vol. I, fascicle 2, pp. 233–271.)
One is practically a translation of the other.

Catalogues and advertising pamphlets of the various clockmaking and watchmaking firms. Only a few of the most important and interesting from the educational side have been listed below. All sales catalogues, parts catalogues, etc., make interesting reading.)
(96) *Description des chronomètres et montres d'art.* Paul Ditisheim, La Chaux-de-Fonds, Suisse.
(97) *The Watch.* Elgin National Watch Co.
(98) *Time Taking, Time Keeping.* Elgin National Watch Co.
(99) *The Timekeeper.* Hamilton Watch Co.
(100) *The Story of Edward Howard and the First American Watch.* E. Howard Watch Works.
(101) *The Howard Watch.* E. Howard Watch Works.
(102) *Illinois Watches and Their Makers.* Illinois Watch Co.
(103) *L'heure.* L. Leroy & Cie.
(104) *Geneva, Switzerland.* Patek, Philippe & Cie.
(105) **The Making of a Marvelous Mechanism.* South Bend Watch Co.
The following seven are all by the Waltham Watch Co.
(106) * (1) *The Why and How of Compensating Watch Balances.*
(107) (2) *Brief and Plain Facts for the Watchmaker.*
(108) (3) *Your Watch.*
(109) * (4) *Information.*
(110) ** (5) *Helpful Information for Watchmakers.*
(111) (6) *Workers Together.*
(112) (7) *The Story of the Waltham Watch.*

(113) CECIL, GEORGE, "Concerning Antique Clocks." *The Connoisseur*, vol. 28, 1910, pp. 31–36, and vol. 29, 1911, pp. 27–33.
(114) Census of the United States (*Statistics on Watches and Clocks and Their Manufacturing Plants*. Vol. X, Part IV, census of 1900, has a special article.)
(115) ** CESCINSKY, HERBERT AND WEBSTER, MALCOLM R., *English Domestic Clocks*. Folio, 353 pp., London (G. Routledge & Sons) 1913.
(116) CHAPUIS, ALFRED, *Histoire de la Pendulerie Neuchâteloise*.
(117) CHAPUIS, ALFRED, *La Montre "Chinoise."* 4to, xiii + 272 pp., Neuchâtel, 1920.
(118) "Clocks Provided with Automatons." *Scientific American Supplement*, Sept. 19, 1896.
(119) "Clocks, Carillons, and Bells." *Journal of the Society of Arts*, London, March 29, 1901.
(120) Clockmakers' Company, *Charter and By-laws*. 8vo, 106 pp., London, 1825.
(121) *Clockmakers' Company, *A Catalogue of Books, Manuscripts, Clocks, Watches, . . . in the Library and Museum of the Worshipful Company of Clockmakers*. 8vo, 116 pp., London, 1875.
(122) *Clockmakers' Company, *A Catalogue Chronologically Arranged of the Collection of Clocks, Watches, etc. . . . presented to the Worshipful Company of Clockmakers . . . by Rev. H. L. Nelthropp*. 2d ed., 8vo, 4 + 85 pp., London, 1900.
(123) Clockmakers' Company, *Catalogue of the Museum*. 2d ed., 8vo, viii + 95 pp., London, 1902.
(124) COLMAN, G. C., "English Bracket Clocks of the Seventeenth and Eighteenth Centuries." *The Connoisseur*, 1902, vol. 2, pp. 191–193.
(125) CONRAD, HENRY CLAY, *Old Delaware Clock-makers*. 34 pp. (Papers of the Hist. Soc. of Del., XX), Wilmington, 1898.
[65] * CUNYNGHAME, HENRY HARDINGE, *Time and Clocks*. 8vo, 3 + 200 pp., London, 1906.
(126) "Curiosities in Clockwork at the Exposition of 1900." *Scientific American Supplement*, 50, 20759 (Oct. 27, 1900).
(127) DAWBER, GUY, "Historic Clocks." *House Beautiful*, 32, pp. 180–182 (Nov., 1912).
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tains those books or pamphlets which are given over entirely to lists of publications. But no one of these claims to be at all complete. It also contains those books which contain a few, quite a few, or even many pages devoted to bibliography. These two groups taken together would be a good starting point for anyone wishing to look up the entire literature on a certain horological subject.

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